FORMULATING X-RAY TECHNIQUES

SEVENTH EDITION

JOHN B. CAHOON, R.T., F.A.S.R.T.

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FORMULATING X-RAY TECHNIQUES

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To
Richard G. Lester, M.D.
Professor and Chairman
Department of Radiology
Duke University Medical Center

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PREFACE TO THE SEVENTH EDITION

Like preceding editions, the present book is intended as a compact text—first for the student x-ray technologist, but also for the experienced technologist in need of a ready reference book. Here student and professional will find the principles of technique of exposure and processing.

The five years that separate the sixth edition from the seventh have confirmed some trends and brought others forward. The emphasis now is on automatic processing, and other such shifts in emphasis are allowed due weight in these pages. An important new section deals with the sensitometric properties of radiographic film. Other new matter develops the present-day 90-second processing chemistry, information on how machine calibration affects technique, and new developments in grids. There are new Basic Exposure Experiments, a new section of tissue absorption, and a new Milleampere-Time Chart ranging from 25 to 1200 Ma. The fixed-kilovoltage system of technique has been treated with a new fullness in keeping with its growing use and value. In the glossary and elsewhere many further terms have been explained, both medical and technological.

Perhaps of greatest interest and importance is the completely revised section of study questions and answers, which includes many additions. To make room for valuable new matter, superseded matter and tables have been compressed or omitted. Few will regret this exchange.

The brevity of this book may shock those who have been encouraged to believe that good radiographic technique may be bought by the page, pound, or hour—or bought in any way except through experience. I have paid for hundreds of lessons by means of hours of hard work and repeated experiments for thirty years. I have been fortunate in being associated with some of the best men in the field who not only taught me the foundation of radiologic technology but also taught me how to learn. As I discussed radiologic technology and at times even argued over it with them, I have continued to be the student. Simplicity, concentration, and economy of time and effort have been the distinguishing features of the teaching methods of these great radiologic technologists which have added to what I consider my knowledge of the field.

I have often thought of men and women who might have been great "chiefs" had they only been able to master the simple and indispensable elements of good technique. Their failure to achieve true pre-eminence has confirmed my long-felt belief that only the man who is himself a good technologist can be a good teacher. The frustrated ones lost their way wandering in a maze of detail.

Instead of being in my classroom you are reading my book. That puts me at a disadvantage in my endeavor to teach you the art of formulating x-ray techniques. The most effective instruction obviously calls for a partnership of pupil and instructor that is best achieved by close association not only in the classroom but in the radiographic room. Nevertheless, I think I have come as close as I can to doing my share on these printed pages. The rest is up to the reader.

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I would like to thank the following for their valued advice and continuous encouragement: Richard G. Lester, M.D.; Mary Duke Seemans; W. C. Davison, M.D.; Paul Capp, M.D.; William F. Barry, M.D.; William Anlyan, M.D.; Boyd T. Worde, M.D.; A. Bradley Soule, M.D.; Barnes Woodall, M.D.; Dorothy and the late Ralph Yergey; Charles Frenzel; Elon H. Clark; and the staff, students, and alumni of the Duke University Medical Center.

No attempt has been made to acknowledge specifically the contributions of the many workers who have played important roles in the development of radiologic techniques; therefore, I would like to acknowledge the following for invaluable material lent to me as well as advice and reproduction right given: The late Arthur W. Fuchs; Clark R. Warren, R.T.; George J. Mahoney, R.T.; Terry Eastman, R.T.; Robert L. Trinkle; Vinita Merrill; Ted Lynch, R.T.; John Watson, R.T.; John Cullinan, R.T.; J. B. Langley; and the many technologists and friends who have written in and given invaluable advice and suggestions. I would also like to thank the following for their many courtesies and for the reproduction rights extended to me over the years: Eastman Kodak Company, E. I. du Pont de Nemours Company, Picker X-Ray Company, General Electric X-Ray Company, Westinghouse X-Ray Company, Keleket X-Ray Company, GAF Film Company, Liebel-Flarsheim Company, Ilford X-Ray Film Company, Low X-Ray Film Company, and the United States Radium Company.

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FORMULATING X-RAY TECHNIQUES

Chapter 1. **RADIOGRAPHIC FILM**

Everyone is familiar with ordinary photographs. These usually show patterns of black metallic silver in varying degrees of density, each duplicating some original pattern of light and shade. Such images are possible because film coated with certain salts of silver can be exposed to radiation—light or x-rays or some other form—and can then be chemically treated so as to produce the silver image. This technique is the basis of common photography and it is the basis of radiographic techniques as well.

COMPOSITION OF X-RAY FILMS

Radiographic film consists of an *emulsion* of finely precipitated silver bromide crystals suspended in gelatin that is coated on both sides of a transparent blue-tinted support called film base. The base furnishes support for the emulsion and provides the correct degree of stiffness for handling. The film base may be of cellulose acetate or, as is more usual nowadays, a polyester.

Silver emulsion

The silver bromide crystals in the emulsion are made by dissolving silver metal in nitric acid. The product of this chemical reaction is silver nitrate. The silver nitrate is then combined with potassium bromide to form silver bromide crystals.

The silver bromide crystals are mixed with gelatin to form the x-ray film emulsion. When examined under the microscope, the emulsion shows itself to be made up of countless tiny crystals of silver bromide embedded in the gelatin. Upon exposure and development, these crystals are changed into irregular clumps and strands of black metallic silver that, as a whole, compose the radiographic image.

Gelatin

Gelatin is chemically a colloid. When placed in water, it will absorb a volume of water several times its dry bulk and become soft and flexible. Though in water at high temperature gelatin will liquefy and go into solution, it will not dissolve in cold water.

These characteristics make gelatin a useful constituent of the x-ray film emulsion. Incorporated in the emulsion, it swells considerably in a cool solution without dissolving, and thus it allows the processing chemicals to act easily on the silver bromide crystals embedded in the emulsion. The fixing bath (hypo) can then remove the unexposed crystals and can harden and shrink the gelatin containing the metallic silver that is left.

Double coating

Each emulsion layer is about one thousandth of an inch thick. Since x-rays pass readily through x-ray films – and also through x-ray intensifying screens when these are used – both sides of the film base are given an emulsion coating. The effect of exposure to x-rays is thus greater than would be possible with an emulsion coated on only one side.

TYPES OF X-RAY FILM

Medical x-ray films

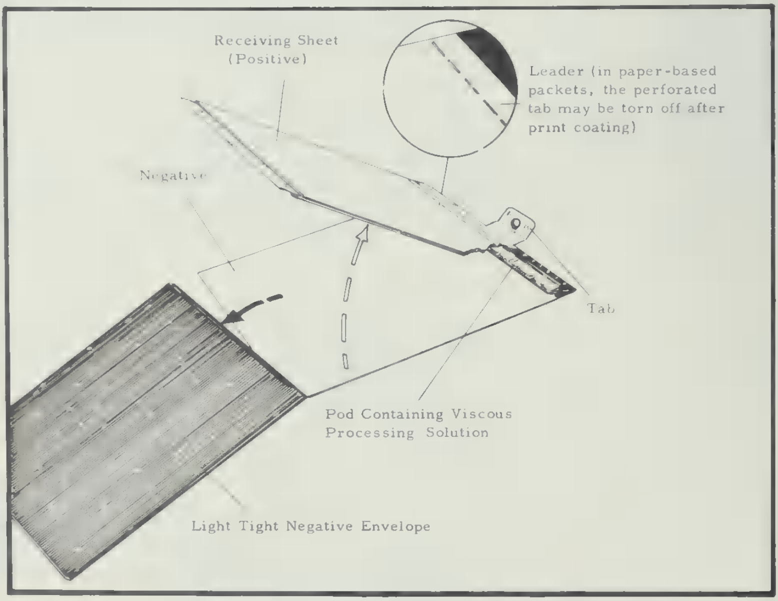
Two types of x-ray film are used for medical radiography – regular-type film used with or without intensifying screens and direct-exposure (non-screen) film. When regular-type film is used without intensifying screens (with cardboard holders), it is slower in *speed* than direct or non-screen type film. Regular-type film is more sensitive to the fluorescent action of intensifying screens than non-screen film. Non-screen film is more sensitive to *direct* x-ray exposure and should never be used with screens. Non-screen film or regular film in a cardboard holder is usually employed for *small parts only*.

Because of its thicker emulsion, non-screen film cannot at this writing be used with automatic processing and is therefore not used as much as it was in the past.

Dental x-ray films

Dental x-ray films are available in a number of sizes, types, and speeds. The sizes may be classified as periapical, interproximal, and occlusal.

Figure 1.1. The Polaroid radiographic packet.


Receiving Sheet
(Positive)
Leader (in paper-based packets, the perforated tab may be torn off after print coating)
Negative
Tab
Pod Containing Viscous Processing Solution
Light Tight Negative Envelope

Periapical dental x-ray film is packed in light-tight, moistureproof paper packets. It is useful in examining the roots of teeth. The emulsions are classified as slow, average, and fast as to sensitivity or speed.

Interproximal (bite-wing) film in the form of packets is used for locating cavities between the teeth.

Occlusal film is larger than the periapical film and is employed for examining larger dental areas that cannot be covered with the periapical film.

Photoradiographic film

Photoradiographic film is a *single*-coated film used for survey chest radiography.

Dosimeter films

Dosimeter films were developed to measure high-energy radiation dosage. Small dental-size packets containing one or more types of film are used. The different films may be selected to record a wide or narrow radiation-dosage range.

Industrial film

Industrial film is used for high-energy radiography and for special radiographic procedures such as mammography.

Duplicating film (for solarization)

Regular film cannot be used for solarization, but there is, at this writing, a special duplicating film, Kodak Type SO-254, which can be used to produce direct positive copies of most medical radiographs. See page 4.

THE POLAROID RADIOGRAPHIC PROCESS

The Polaroid radiographic packet

The three primary parts of the Polaroid radiographic packet are (*a*) the negative, which carries the photosensitive emulsion, (*b*) the pod, a metallic foil envelope which contains the viscous processing solution, and (*c*) the receiving sheet, which accepts the positive image from the exposed negative. The radiograph obtained may be a paper-based reflection print (Type 3000X and Type 1001) or a film-based (polyester) translucency (Type TLX film).

The remaining parts, shown in Figure 1.1, permit the negative, the receiving sheet, and the viscous processing solution to perform their collective function of producing a finished radiograph.

With Type TLX film, the final result is a translucent positive radiograph, which can be viewed either by transmitted light, such as that from a standard illuminator, or by reflected light, such as that available from room illumination. With Type 3000X and Type 1001, the result is a positive radiographic print which can be viewed by reflected light only.

When Polaroid Type 3000X or Polaroid Type TLX packets are exposed to x-radiation in conjunction with a standard blue-emitting, high-speed fluorescent screen, radiographs of satisfactory density are produced with reductions in radiation exposure ranging from 50 to 84 per cent, depending upon the wet-process film/screen combination used for comparison.

Exposure

Figure 1.2 schematically represents the exposure of a Polaroid radiographic packet. The fluorescent screen emits visible light when excited by x-rays. This visible image is recorded as a latent image on the photosensitive surface of the negative. The exposed Polaroid radiographic packet with its latent image is processed by drawing it through a set of pressure rollers which burst the pod and spread the viscous processing solution between the negative and the receiving sheet. The developing agent in the processing solution reacts with *exposed* silver halide particles and forms a visible, negative image by reducing the silver ions to metallic silver. While this negative image is being formed, another component of the processing solution, a photographic fixing agent, dissolves *unexposed* silver halide particles by forming soluble complexes with their silver ions. These complexes diffuse through the thin layer of viscous processing solution to the receiving sheet, where they contact substances which free the silver ions from their complexes with the fixing agent and make them subject to reduction to metallic silver by the action of the developing agent. The metallic silver so formed is then deposited on the receiving sheet to create the *positive* radiographic image. This entire diffusion transfer reversal process is accomplished in *ten seconds with Type 3000X*, in *sixty seconds with Type 1001*, and in *forty-five seconds with Type TLX*.

Figure 1.2. The exposure of a Polaroid radiographic packet.

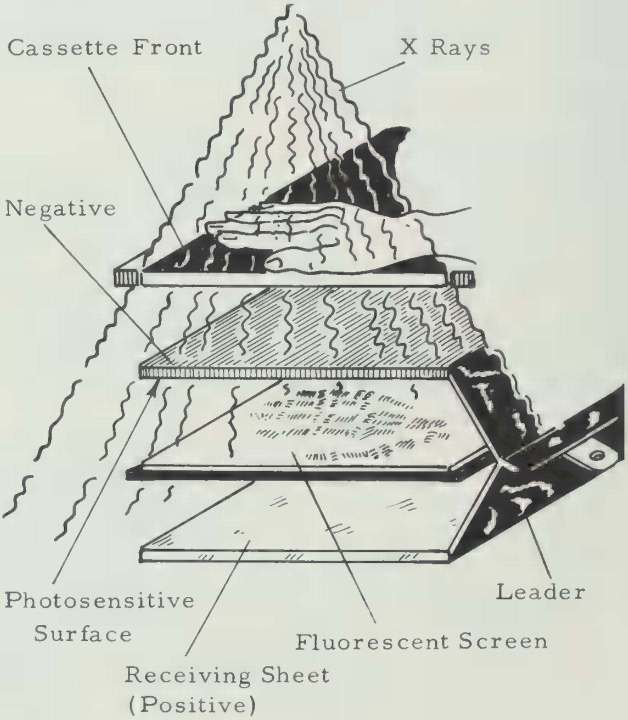
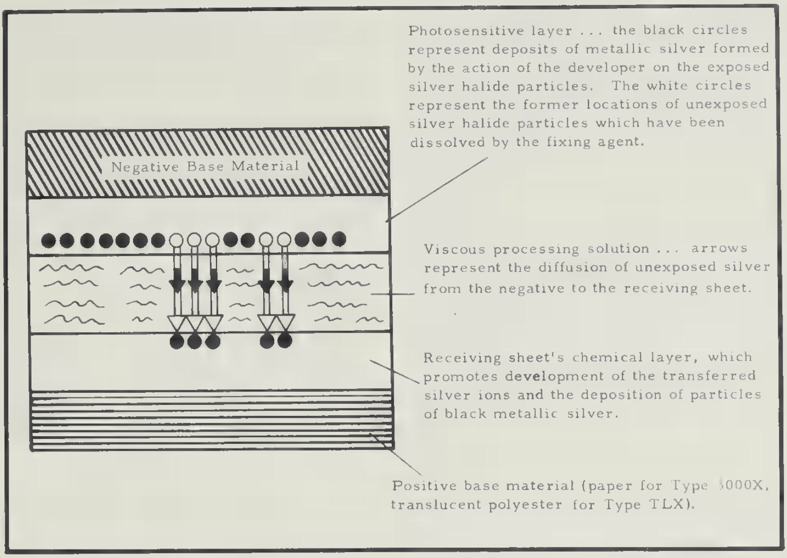


Figure 1.3 shows the process schematically. The width of the layers has been exaggerated in this illustration for clarity.

You can perhaps better understand why the final radiograph bears a positive image if you remember that it is the silver ions of the *unexposed* silver halide particles that are the source of the metallic silver deposits which form the radiographic image.

Figure 1.3. The process of diffusion transfer shown schematically.



Photosensitive layer . . . the black circles represent deposits of metallic silver formed by the action of the developer on the exposed silver halide particles. The white circles represent the former locations of unexposed silver halide particles which have been dissolved by the fixing agent.

Viscous processing solution . . . arrows represent the diffusion of unexposed silver from the negative to the receiving sheet.

Receiving sheet's chemical layer, which promotes development of the transferred silver ions and the deposition of particles of black metallic silver.

Positive base material (paper for Type 3000X, translucent polyester for Type TLX).

Figure 1.4. Radiograph of lateral skull made with Polaroid TLX film.

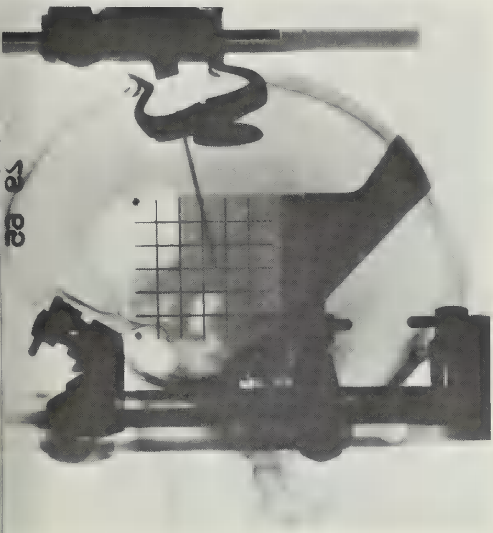
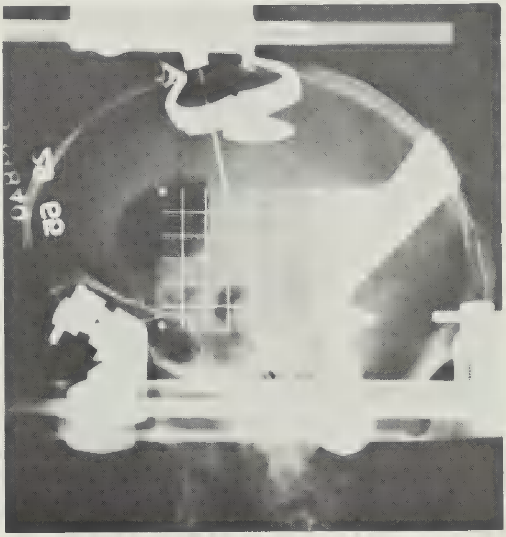


Figure 1.5. Radiograph of skull of Figure 1.4 made with conventional radiographic film.



Coating

Within one hour after processing, Polaroid radiographic prints should be treated with the print-coating solution that is provided (see instructions accompanying the film). This simple but important treatment quickly neutralizes the small amount of processing solution that remains in the receiving sheet when it is stripped from the negative. Moreover, as soon as the print-coating solution dries, it leaves behind a durable plastic film which protects the surface of the radiograph from scratches, moisture, and atmospheric contaminants which can attack the silver image.

FILM STORAGE AND HANDLING

General

A film is a delicate material and it should not be handled carelessly or roughly. It is sensitive to heat, light, x-rays, radium, chemical fumes, pressure, rolling, bending, etc., and any one of these is capable of adversely affecting the emulsion. Radiographic films can, however, be handled safely in accordance with all the various radiographic needs of the x-ray technologist as long as he knows what he must do to avoid the production of foreign marks, referred to as *artifacts.* From a radiographic standpoint an *artifact* is a mark which is foreign to the x-ray image and which is not necessarily imposed on the film by the action of x-rays.

Radiographic film is packed in metal foil and paper wrapping to protect it from light and moisture, and each sheet is enclosed in a folder of chemically pure interleaving paper. The DuPont and Ansco film companies supply film with or without interleaving paper.

Heat

Unexposed and unprocessed film should always be kept in a cool, dry place. It should never be stored in basements or near steam pipes or other sources of heat. High temperatures exert injurious effects on the emulsion, causing loss of contrast and the production of fog.

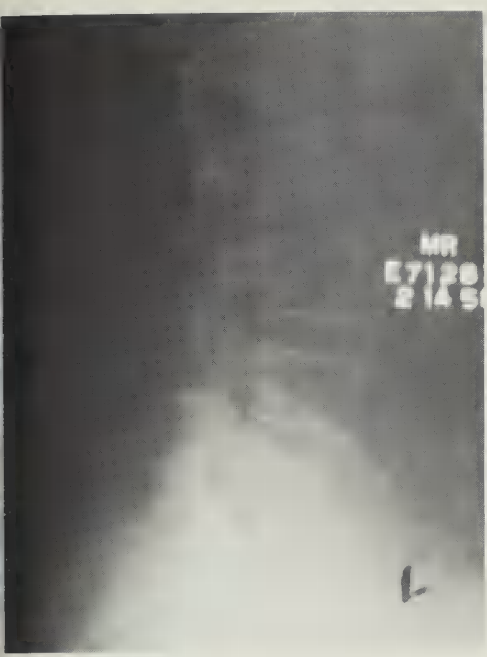
An approximate guide to the storage of film is as follows. If the film is to be used in two months, it can withstand temperatures up to 75° F. without fog. If stored at 60° F., it can be stored for six months, and for one year at 50° F. Ideal storage is 50° to 70° F. and 40 to 60 per cent relative humidity.

Radiation

All radiographic film must be suitably protected from the action of x-rays and all other forms of radiation by the use of lead-lined walls or lead-lined film bins or by keeping the film at a safe distance from radium and x-ray exposure.

Expiration date

Film should be used before the expiration date since film aging causes loss in *speed* and *contrast* and will result in a *mottled* appearance on the



igure 1.6. Radiograph of lateral lumbar spine, verexposed.

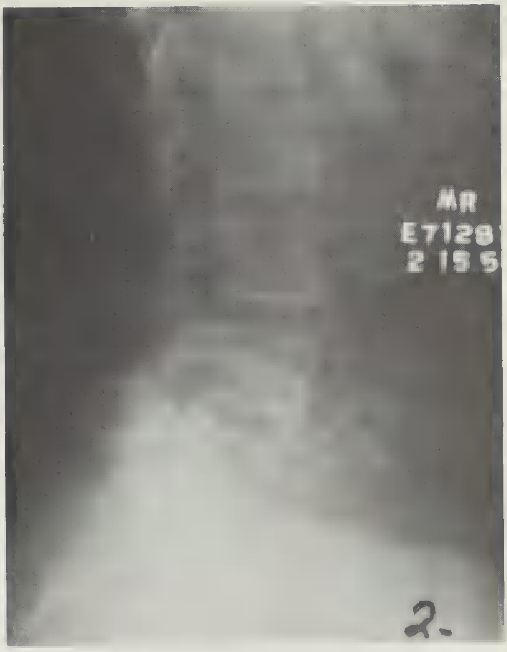
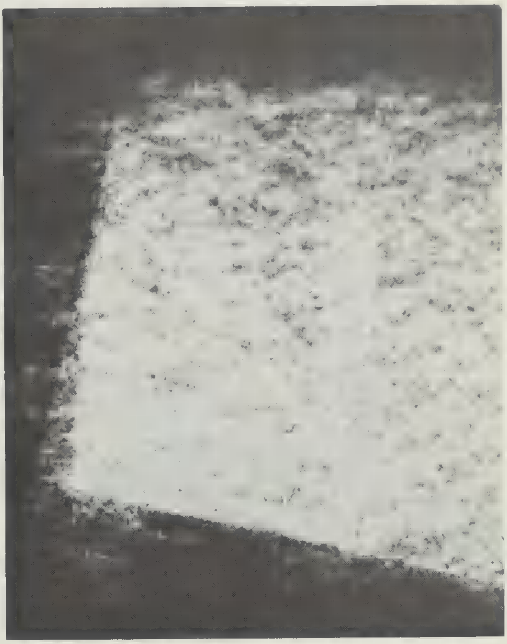


Figure 1.7. Radiograph of same patient as in Figure 1.6 with 50 per cent reduction in exposure.

igure 1.8. Non-exposed film from the same box s used for Figure 1.6 and 1.7. Note the mottle.

Figure 1.9. Mottle caused by "white light" leak.



finished radiograph. The expiration date will be found on each box of film.

Figure 1.6 shows a lateral lumbar spine thought to be overexposed. Figure 1.7 is a radiograph of the same patient with a reduction of 50 per cent in exposure employing the same cassette. Figure 1.8 is a film taken from the same box of films and processed in the normal manner (without radiographic exposure). This film shows *mottle* from old, outdated film.

Mottle is also caused by "white light" leak in the film bin. The interleaving paper when struck by white light gives the mottle to the film (Figure 1.9). Most film is now supplied without interleaving paper.

Handling

When handled, radiographic films should be held as near the edges as possible. The hands should be clean and dry, and hand cream should be avoided. The use of rubber gloves should also be avoided.

Loading and unloading film

Generally, there are two types of containers in which medical x-ray film can be held during exposure—*cassettes* and *cardboard holders.* Recently there has appeared on the market a new type of disposable cardboard holder. The choice of holder depends upon the part to be radiographed and the exposure technique. Loading and unloading film is of great importance and requires care. When loading a cassette, place the film *without the paper* in the bottom of the cassette.

Static electricity

When two non-conductors such as interleaving paper and film are sepa-

Figure 1.10. Smudge static marks.

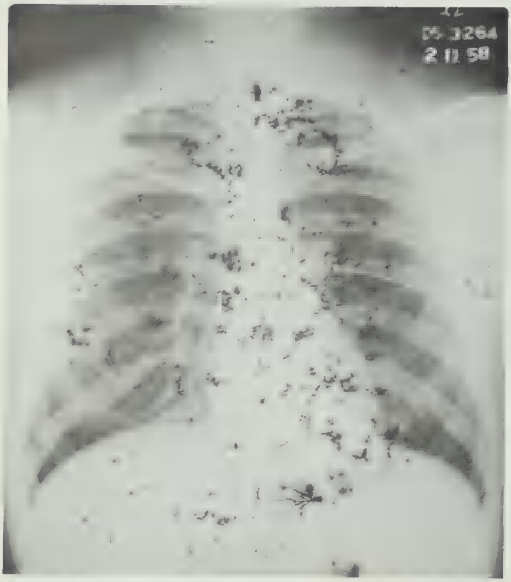
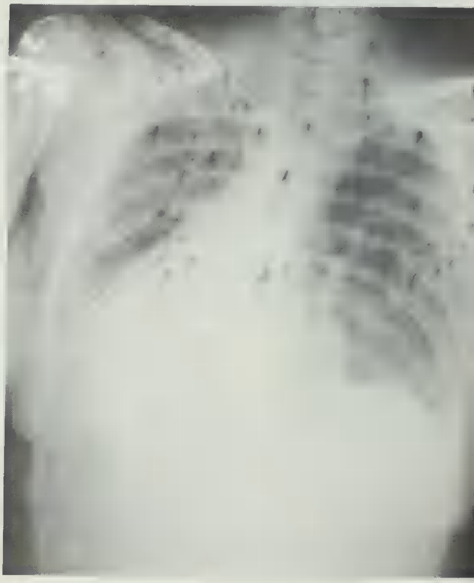


Figure 1.11. Tree static marks.



rated quickly, a static charge may be established. Electrical charges may be generated when a cassette is open and the two screen surfaces are rapidly separated, or when a film is pulled from the cassette.

The rubbing together of clothing, especially silk, nylon, and rayon, while working in the processing room can build up a static charge.

The three classifications of static markings commonly found on radiographs are *tree static, crown static,* and *smudge static.* Very rapid motions such as removing a film from interleaving paper can build up a charge sufficient to discharge in the form of tree static when the film is touched by the technologist, or when interleaving paper breaks contact with the film. Crown static most often is the result of the rapid withdrawing of a film from a tight or new box of film. Smudge static occurs when a discharge follows a path induced by dust, lint, or a rough intensifying screen surface.

While grounding the loading bench provides the simplest solution to static problems, moisture in the air around the film area is the greatest aid in the prevention of static. The higher the moisture content of the air, the less chance there will be for static to appear. This is the reason why there is less static with manual processing than with automatic processing.

Film identification data

In studying radiographs, the radiologist must be able to determine readily the side of the body examined, the direction of the central ray, and, if stereoradiography is employed, the direction of the tube shift. The most effective and accurate way to incorporate these data in the radiograph is by means of markers made of lead or other suitable radiopaque materials that can be placed on the cassette or film holder before the exposure is made. Letters, numerals, and holders for this purpose may be obtained from any dealer in x-ray supplies.

It is often necessary to incorporate in the radiograph the name and address or institution of the radiologist, the patient's name, the case number, and the date of the examination. From the standpoint of appearance, efficiency, and medicolegal precautions, the photographic method is excellent for such markings.

FILM TESTS

Every radiologic technologist should learn to make film tests to compare brands of film for contrast and speed values. He should also learn to run chemical tests. Tests should be made with both a step wedge and body tissues or phantoms, for each brand of film or each brand of chemical to be tested. It is essential to use the same cassette and the same subject matter and to process all the films at the same time. Films should be tested for low and high kilovoltage. All films should be filed for future reference in order to evaluate and compare the film emulsions' contrast and speed characteristics at a later date with newer film or newer chemistry.

By running a standard test employing the technique used each day in the department, one can easily check the speed and contrast characteristics of a new film by making identical exposures for comparison.

Rather than use patients for film and chemical evaluation, the author prefers to use phantoms and a step wedge. The phantoms shown in Figures 1.12 and 1.13 consist of carefully selected adult human bones, embedded in transparent non-granular plastic. This plastic has the same absorption and secondary-radiation-emitting characteristics as living tissue. One may repeat an experiment, regardless of dosage, as often as necessary with no danger of excess radiation. One may also make critical detailed studies of bone-structure and sharpness comparisons.

The tissue-equivalent plastic step wedge, Figure 1.14, is an excellent tool for research and comparative studies. It consists of ten separate blocks which can easily be disassembled and rearranged to obtain different thicknesses. Embedded in the top are several test objects: a 2 x 2 x 2 cm. lead plate for measuring magnification, distortion, and secondary radiation; five parallel pieces of stainless steel wire to determine sharpness and visibility of detail; a cube of human bone; a gelatin capsule, $1/2$ cm. in diameter, containing bone dust; and an identical capsule containing air.

The steps are wide enough to produce density strips on a radiograph which can be measured with a densitometer. Microdensitometer measurements are possible across the shadow of the stainless steel wire. Densitometer measurements can also be made of shadows cast by other test objects.

The wedge is large enough to be placed across two cassettes containing screens and film, permitting screen and film evaluations with a single exposure. These absorption and secondary-radiation-emission characteristics

Figure 1.12. Phantom of the knee joint: human bones embedded in a special plastic.

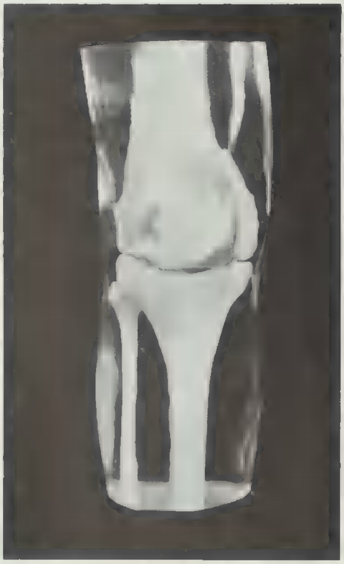
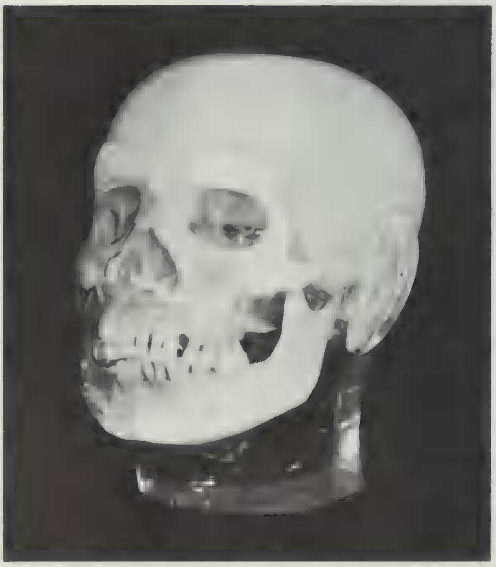


Figure 1.13. Phantom of a human skull, embedded in plastic.



of the wedge have proved remarkably similar to those of human tissues in the voltage range between 50 and 150 Kv.P.

Such a wedge is valuable in teaching and testing. It demonstrates all the factors which control and affect the quality of the radiograph. It also permits studies of image intensifiers and their allied equipment.

SENSITOMETRY

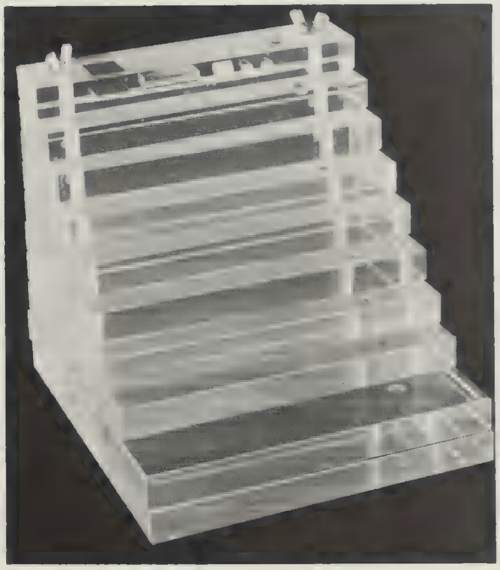
Radiologic technology is becoming so highly specialized today that we must know something about sensitometry in order to evaluate scientifically various types of films, exposure, and development.

A film's response to exposure

The effects of changes in exposure and processing conditions on the density of a processed radiographic film are well known in a qualitative way. We do not need to be convinced that if the tube current or the development time is increased, the density is increased; if the exposure time or the development temperature is decreased, the density is decreased. When it comes to quantitative problems, however, our first ideas may be inadequate. For instance, if the milliamperage is doubled, is the resulting net density doubled? For low-density direct x-ray exposure, yes; for fluorescent screen exposures and for direct exposures to more than a moderate density, no.

Just what are the relationships between exposure and processing conditions, on the one hand, and film response on the other? The study and meas-

Figure 1.14. The step wedge made of plastic, described in the text.



urement of these relationships is known as *sensitometry;* and the properties of a film which affect or govern the relationships are known as its *sensitometric properties.* A knowledge of the response of radiographic films to radiation—i.e., of the sensitometric properties of films—will aid in assessing beforehand the effect of a proposed change in radiographic technique on the appearance of a radiograph. It will help in assuring that a particular film is used to the best advantage—in terms of visibility of significant detail—that the particular radiographic and viewing conditions will permit. A knowledge of the sensitometric properties of film is, or course, essential when quantitative measurements are to be made with films—for example, in radiation monitoring or in the quantitative measurement of the amount of scattered radiation removed by a certain Potter-Bucky grid.

Although the illustrative examples are drawn largely from medical radiography, the same principles apply to industrial radiography with either x-rays or gamma rays.

Exposure

One difficulty in discussing film properties arises from the different radiographic meanings assigned to the word "exposure," depending upon its context. Exposure, as the term is used here, is equal to the intensity of the radiation reaching a given area of the film multiplied by the time during which it acts. It is thus the amount of energy reaching a particular area of the film and causing a particular density on the processed film. In this usage, exposure may be specified in either absolute units (ergs per square centimeter of visible or x-radiation, or roentgens of x-rays) or in relative units, where one particular exposure is taken as a reference and all others are specified in terms of the one chosen. It is occasionally necessary, as in the monitoring of radiation, to stick with absolute units for exposures, but in most cases *relative exposure* is much more convenient and equally useful. Relative exposure will be the kind oftenest dealt with in this discussion. Where exposure is in absolute units, the context will make it clear.

Photographic density

The action of radiation—visible or x-ray—on a film becomes apparent only in the varying degrees of blackening in the processed film. Photographic density is defined as the quantitative measure of film blackening. Where no danger of confusion exists, photographic density is spoken of merely as *density.*

The characteristic curve

The most common, as well as the most convenient and most instructive, method of representing the response of a film to light or x-rays is by means of the characteristic curve (Figure 1.15). This curve is sometimes referred to as the *sensitometric curve* or the *H and D curve,* after Hurter and Driffield, who in 1890 first used it. It expresses the relationship between the logarithm of the exposure (horizontal axis) and the resulting density (vertical axis).

Characteristic curves are obtained by giving a film a series of known ex-

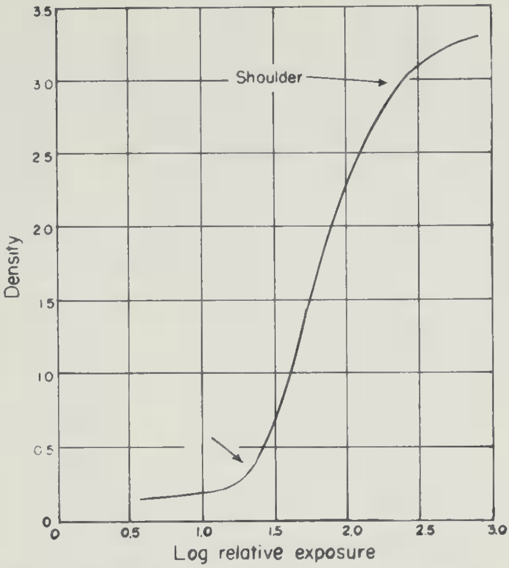


Figure 1.15. The characteristic curve of a typical medical x-ray film, exposed with intensifying screens of calcium tungstate.

posures and then plotting density against logarithm of exposure or logarithm of relative exposure. In radiography, the ratios of exposure are usually more significant than the absolute values of the exposures themselves. Therefore it is usually sufficient—and always more convenient—to express the exposures to the film in terms of some particular exposure, thus giving a relative scale.

There are great advantages in using a logarithmic scale for the exposure axis of the characteristic curve. If the kilovoltage remains constant, the ratios of the exposures reaching the film through two different regions of the subject are always the same, no matter what the values of tube current (milliamperage), time, or focus-film distance may be. On a logarithmic scale, such as is used on characteristic curves, two exposures whose ratio is constant will always be separated by the same distance on the exposure scale, no matter what their absolute values. Thus, two exposures, one of which is three times the other, will always be separated by 0.48 on the logarithmic exposure scale, entirely independent of the absolute values of the exposures or of the units in which the exposure is stated.

The shape of the curve *does not depend* on the subject or its scattering properties, on the kilovoltage, or on the milliamperage. However, the shape of the curve for a film exposed to light—as in radiography with fluorescent screens, photoradiography, or cineradiography—does depend upon the type of film, the color of the exposing light, and the processing conditions. All that the film "knows" is that it is being exposed to various intensities of light, and the characteristic curve shows graphically how it responds to these intensities. The characteristic curve of a film exposed to x-rays or gamma rays (with or without lead foil screens) depends only on the film type and the processing conditions, not upon the quality of the x-radiation, and hence not upon the kilovoltage or the scattering characteristics of the subject.

CONTRAST

Radiographic contrast between two areas of a radiograph is the difference between the densities of those two areas. Fundamentally, the images of two regions of slightly differing x-ray absorption can be differentiated in the finished radiograph only by the radiographic contrast between them. Radiographic contrast depends upon both *subject contrast* and *film contrast.*

Subject contrast is the ratio of x-ray or gamma-ray intensities transmitted by two selected portions of a subject (see Figure 1.16). Subject contrast depends upon the nature of the subject, the quality of the radiation, and the intensity and distribution of the scattered radiation, but is independent of the other exposure variables such as time, milliamperage, and distance, and of the characteristics or processing of the film.

Film contrast refers to the slope (steepness) of the characteristic curve of the film. It depends upon the type of film, the processing it receives, and the density. It is independent, for practical purposes, of the quality and distribution of the x-radiation reaching the fluorescent intensifying screens or the x-ray film (indirect exposure or lead-foil screen techniques).

It is this latter quantity, film contrast, with which this section is concerned. Since the shape of the characteristic curve is independent of the major radiographic variables, film contrast can be considered quite independently of subject contrast, although, as pointed out above, the two contribute equally to the radiographic contrast that enables one area to be distinguished from another when the finished radiograph is viewed on the illuminator.

As can be seen in Figure 1.15, the slope, or steepness, of the characteristic curve at first increases with increasing density (the toe); then, in the middle the range of densities becomes fairly straight; and finally, at higher densities the slope decreases as density increases (the shoulder). The shoulders of the curves for industrial x-ray films, and of the direct-exposure type of medical x-ray films, come at densities far above those that can be viewed on available illuminators.

Changes in the slope of the characteristic curve have a definite relationship to the visibility of details in the radiograph. For example, two slightly different thicknesses in the subject will transmit slightly different exposures to the film. The exposures will have a certain ratio, i.e., will have a certain log exposure difference between them. This ratio—and hence the log exposure difference—will be fixed if the kilovoltage remains unchanged, despite any changes in exposure time, milliamperage, or focus-film distance.

On some x-ray machines, a change in milliamperage causes a small

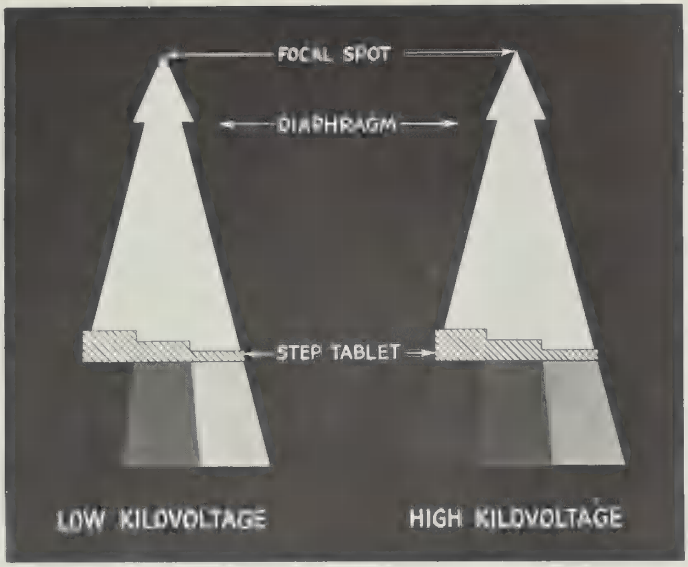


Figure 1.16. With one and the same subject, the beam of lower kilovoltage (left) produces a higher subject contrast than does the beam of higher kilovoltage (right)

change in the peak kilovoltage or the high-voltage wave form, for purely electrical reasons. Changes of this type are rarely of significance in diagnostic or industrial radiographic practice, but they sometimes give results which appear to be a violation of the rule given here.

The difference in densities corresponding to the two exposures will depend upon just where on the characteristic curve they fall; the steeper the curve, the greater will be the density difference. This means that a certain log exposure interval in the middle of the curve of Figure 1.15 will correspond to a greater density difference than the same interval at either end. This is demonstrated in Figure 1.17. B, C, and D are radiographs of the test object shown in A. The radiographs differ only in the milliampere seconds used to make them, that is, upon the portion of the characteristic curve on which the densities fall. The details are more clearly visible on radiograph C than on B or D, because C uses the steep central portion of the curve (where the film contrast is highest), while B and D use the much flatter toe and shoulder.

The type of example dealt with qualitatively, above, also lends itself to quantitative treatment. The slope of a curve at a particular point is expressed as the slope of a straight line drawn tangent to the curve at that point. When applied to the characteristic curve of a photographic or radiographic material, the slope of such a straight line is called the *gradient* of the material at the particular density.

Now consider two slightly different thicknesses in a subject, and assume

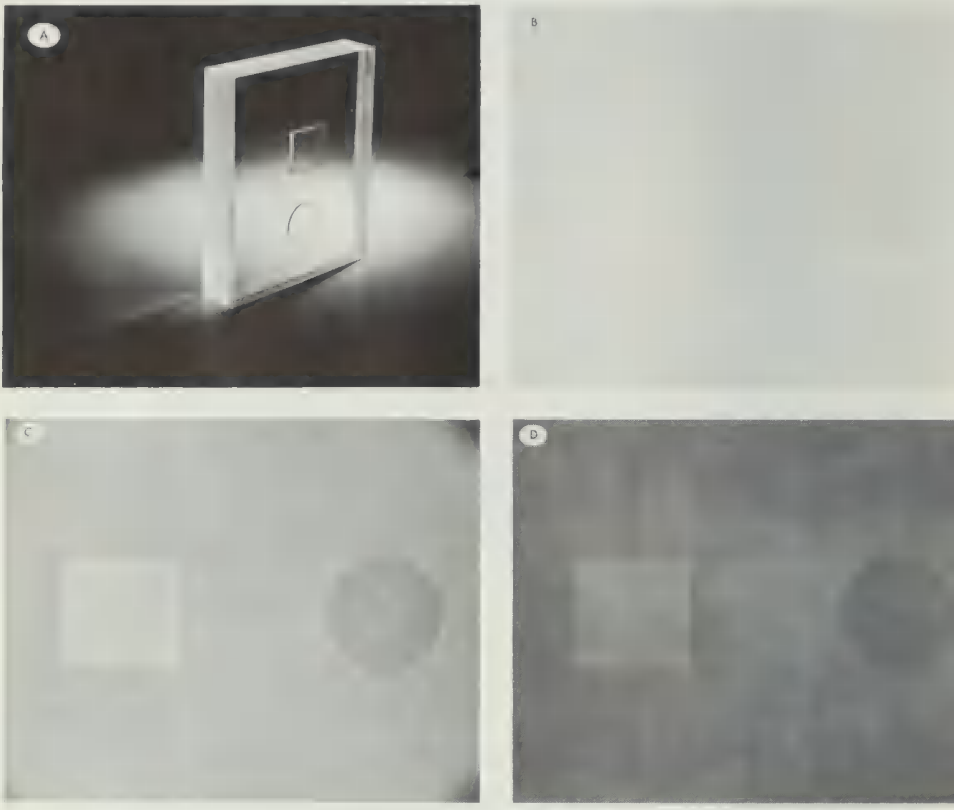


Figure 1.17. A is the photograph of a plastic test object. B, C, and D, are radiographs of this test object made on a screen-type film at increasing exposure times, all other radiographic factors remaining constant. Note that the structure of the test object is most easily visible in the middle range of densities (C), where the characteristic curve (see Figure 1.15) is steepest. Figures 1.16 and 1.17 are from *Sensitometric Properties of X-Ray Films*, published by Radiography Markets Division, Eastman Kodak Company.

that at a certain kilovoltage the thinner section transmits 20 per cent more radiation than the thicker. The difference in logarithm of relative exposure ($\Delta \log E$) is 0.08 and is independent of the milliamperage, exposure time, or focus-film distance. If this subject is radiographed with an exposure that puts the developed densities on the toe of the characteristic curve where the gradient is 0.5, the x-ray intensity difference of 20 per cent is represented by a density difference of 0.04, corresponding to a difference in light transmission of 10 per cent. If the exposure is such that the densities fall on that part of the curve where the gradient is 3.4, the 20 per cent intensity difference results in a density difference of 0.31 (or a difference in light transmission of 104 per cent).

In general then, if the gradient of the characteristic curve is greater than 1.0, the intensity ratios, or subject contrasts, of the radiation emerging from the subject are exaggerated in the brightness ratios of the radiograph, and the higher the gradient, the greater is the degree of exaggeration. Thus, at densities for which the gradient is greater than 1.0, the film acts as a contrast amplifier. Similarly, if the gradient is less than 1.0, the subject contrasts are less apparent in the radiographic reproduction.

It is often useful to have a single number to indicate the contrast property of a film. This need is met by a quantity known as the *average gradient,* defined as the slope of a straight line joining two points of specified densities on the characteristic curve. In particular, the specified densities between which the straight line is drawn may be the maximum and minimum useful densities under practical conditions. The average gradient, then, will indicate the average contrast properties of the film over this useful range. For a given film and developing technique, the average gradient will, of course, depend upon the density range chosen. The net density range of 0.25 to 2.00 is often used for the determination of the average gradient of medical x-ray films. Industrial radiographs are usually exposed to higher densities, and the gradient of industrial x-ray films is often determined over the net density range of 0.5 to 2.5.

Gamma is another quantity used (particularly in photographic literature) to express film contrast. Gamma is defined as the slope of the straight-line portion of the characteristic curve. In radiography, gamma is a less useful concept than average gradient because the characteristic curves of many radiographic, photofluorographic, and cinefluorographic films have relatively short straight-line portions. In addition, the straight-line portion may easily fail to coincide with the density range that is most useful radiographically. Thus, gamma may give no information about portions of the characteristic curve which are often used in practice.

Densities of radiographs

The net density range of 0.25 to 2.00 is often used for the determination of the average gradient of medical radiographic films because surveys have shown that it covers the range of densities most commonly encountered in the diagnostic areas of medical radiographs. The average gradient over this range, then, is a useful general criterion for the contrast of medical x-ray films.

This should not be construed to mean that no density above 2.00 (net) is useful in medical radiography. The slope of the characteristic curve (and hence the film contrast) remains relatively steep for screen-type films up to a total density of about 3.0. The slope of the curves for direct x-ray films continues to increase to densities much higher than this. The relatively low maximum density used in much medical radiography results from a combination of circumstances. First, most medical x-ray illuminators are not bright enough for viewing high densities, particularly if the general illumination level in the room is high. Assume that a chest, for example, is radiographed with a technique such that the lowest density of diagnostic interest is at the currently accepted level, but the highest density of diagnostic interest is in the neighborhood of 3.0, and that this radiograph is viewed on a bright illuminator. The observer's eyes would then be so dazzled by the light coming through the images of the heart and diaphragm that he could not properly interpret the high-density areas.

Average gradients of industrial x-ray films are evaluated over the density range 0.5 to 2.5, and densities up to 4.0 are routinely used. This is because the characteristic curves for the common industrial x-ray films are similar, in that the contrast continues to increase up to very high densities. Further, industrial radiographic specimens are often fairly uniform in thickness, given radiographs with restricted density ranges. In addition, industrial x-ray departments are commonly equipped with high-intensity illuminators which incorporate means to limit the bright light to a small area of the radiograph and thus to avoid dazzling the observer.

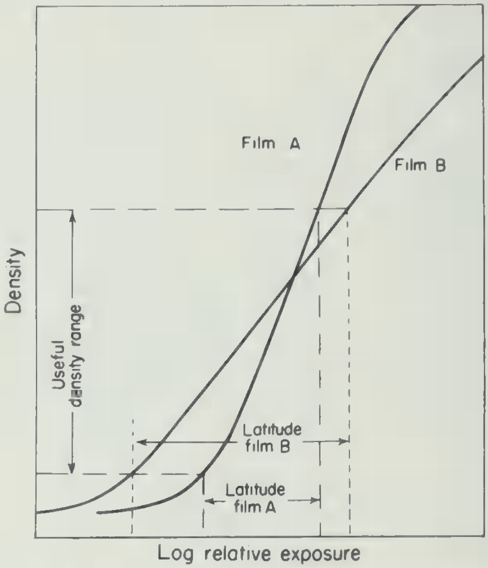


Figure 1.18. Characteristic curves (hypothetical) of two radiographic films. A has high contrast; B has low contrast. The range of exposures within the range of useful density – i.e., the latitude of the film – depends on the average gradient.

Latitude

Figure 1.18 shows the characteristic curves of two hypothetical films. Film A has a high contrast – a high average gradient – and film B has a lower contrast. Film A will differentiate more strikingly between structures of slightly differing x-ray transmission than will film B. However, film B will cover a much wider range of x-ray intensities within a particular density range than will film A – i.e., film B has the greater latitude.

In using a film such as B at a particular kilovoltage (i.e., with the subject contrast fixed), radiographs can be made over a wider range of milliampere-second values without affecting their radiographic value than with film A, because film B has the greater latitude. On the other hand, no radiograph on film B will show detail as clearly as a correctly exposed radiograph on film A, because film A has the higher contrast. Thus latitude and contrast are reciprocal quantities. For the same range of useful densities, it is impossible that a film of high contrast should have wide latitude or that a film with wide latitude should have high contrast.

High film contrast is desirable in certain types of radiography since it is necessary for making faint structures visible in the radiograph. In other words, the ability of a film to amplify subject contrast is well worth the minor inconvenience of having to be fairly precise in the choice of exposing conditions. *In high-contrast radiography there is very little room for exposure errors.*

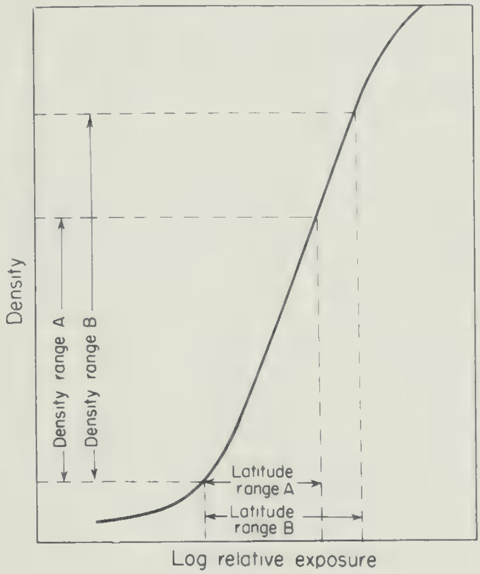


Figure 1.19. The characteristic curve (hypothetical) of a radiographic film. The latitude of a particular film depends on the range of densities which is considered useful.

Latitude is based on the use of a particular density range. If the density interval can be increased—specifically, if higher densities can be used—latitude can be increased with no diminution in contrast. This is illustrated in Figure 1.19. The amount by which latitude can be thus extended is limited by one of two factors. In medical radiography, the limit is most often set by the point at which the upper density falls on the shoulder of the characteristic curve, where the slope of the curve (and hence the film contrast) decreases to values that are not useful. In industrial radiography, the films maintain their contrast to very high densities and the upper density limit is usually governed by brightness of the available illuminators.

LOGARITHMS

Since logarithms are used a great deal in the preceding material, a brief discussion of them is included here. A more detailed treatment will be found in some handbooks and intermediate algebra texts.

Let us begin by defining the term *power.* The power of a number is the product obtained when it is multiplied by itself a given number of times. Thus $10^3 = 10 \times 10 \times 10 = 1{,}000$; $5^2 = 5 \times 5 = 25$. In the first example, 1,000 is said to be the third power of 10; in the second, 25 is the second power of 5, or 5 is raised to the second power. The figure ^{2} is known as the *exponent.* Fractional exponents are used to denote roots.

Example:

$$n^{a/b} = \sqrt[b]{n^a}; \quad 16^{1/2} = \sqrt{16} = 4;$$

$$10^{2.50} = 10^{5/2} = \sqrt{10^5} = 316.$$

Negative exponents indicate reciprocals of powers. Thus:

$$n^{-a} = n^{1/a}; \quad 10^{-2} = 1/100 = 0.01.$$

The *common logarithm* of a number is the exponent of the power to which 10 must be raised to give the number in question. For example, the logarithm of 100 is 2. The logarithm of 316 is 2.50, or log 316 = 2.50; the logarithm of 1,000 is 3, or log 1,000 = 3. It is also said that 1,000 is the antilogarithm of 3, or antilog 3 = 1,000.

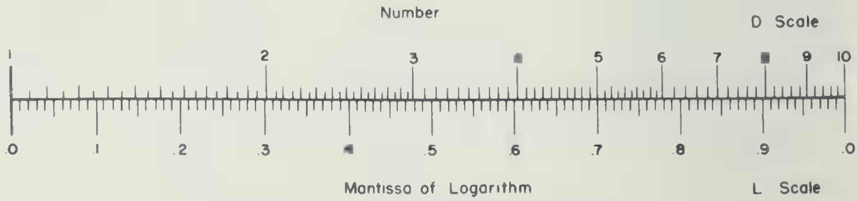


Figure 1.20. Scale for determining logarithms.

Logarithms consist of two parts: a decimal which is always positive, called the *mantissa*; and an integer which may be positive or negative, called the *characteristic.* In the case of log 316 = 2.50, 50 is the mantissa and 2 is the characteristic. The mantissa may be found by reference to a table of logarithms, by the use of a slide rule (D and L scales), or by reference to Figure 1.20. No matter what the location of the decimal point may be, the logarithms of all numbers having the same figures in the same order have the same mantissa.

The characteristic of the logarithm is determined by the location of the decimal point in the number. If the number is greater than 1, the characteristic is positive and its value is 1 *less* than the number of digits to the left of the decimal point. If the number is less than 1 (i.e., a decimal fraction), the characteristic is negative, and has a numerical value of 1 *greater* than the number of zeros between the decimal point and the first integer. A negative characteristic of, say, 3 is written $\bar{3}$ . . . . to indicate that only the characteristic is negative, or 7 . . . . −10.

From Figure 1.20 we see that the mantissa of the logarithm of 20 is 0.30. The characteristic is 1:

log 20 = 1.30
log 40 = 1.60
log 80 = 1.90
log 160 = 2.20
log 200 = 2.30
log 2000 = 3.30
log 20000 = 4.30
log 0.2 = $\bar{1}$.30
or 9.30 − 10

When a series of numbers increases by a *constant* factor (e.g., the series 20, 40, 80, 160 or the series 20, 200, 2,000, 20,000), their logarithms have a *constant* difference, in these cases, 0.30 and 1.00 respectively. In other words, a *constant* increase in the logarithm of a number means a constant percentage increase in the number itself.

SENSITIVITY (SPEED)

The contrast properties of a film are indicated by the *shape* of the characteristic curve. Another value, which can be obtained from the characteristic curve, is the speed or the sensitivity of the film to radiation. It is indicated by the *location* of the curve along the exposure axis. Speeds of radiographic films are usually given as inversely proportional to the exposure required to reach a certain density.

The exposure on which speed values are based may be given in absolute units—the total light energy (in ergs per square centimeter) for film used with fluorescent or photofluorographic screens, or incident roentgens of a particular radiation quality for films intended for direct exposure. In practical applications of x-ray films, however, it is usually more convenient, and equally useful, to deal with *relative speeds*. In this method, speeds are expressed in terms of the speed on one particular film, to whose relative speed the value 100 is arbitrarily assigned. For example, if one film requires half the exposure to reach a certain density as does a second, and if the slower is chosen as the standard, the faster will have a relative speed of 200. The choice of film to which the speed of 100 is to be assigned is purely arbitrary, and may be made on the basis of convenience alone. In this discussion relative speeds are used exclusively.

In a group of characteristic curves, those for the faster films will lie toward the left of the diagram, in the region of smaller values of logarithm of relative exposure, or, phrased differently, in the region where a smaller exposure is needed to produce a certain density. Conversely, the curves for the slower films will lie toward the right of the diagram in the region where the relative exposure, or its logarithm, is large. From such a diagram, relative exposures to produce a fixed density can be read off, and the relative speeds will be inversely proportional to these exposures. In Figure 1.21 the characteristic curve for film C lies to the left of that for film D, indicating that film C is the faster. The separation between the two curves indicates the magnitude of the speed difference.

For medical x-ray films, a density of 1.00 above the density of the base plus fog—i.e., a net density of 1.00—has been found a suitable density at which to compute film speeds. The speeds of industrial x-ray films are usually determined at a density of 1.5 above base plus fog, reflecting the higher average density of industrial radiographs. Although net densities of 1.00 or 1.50 are usually the values used in standards, specifications, and the like, other densities may be used to suit the conditions of a particular problem.

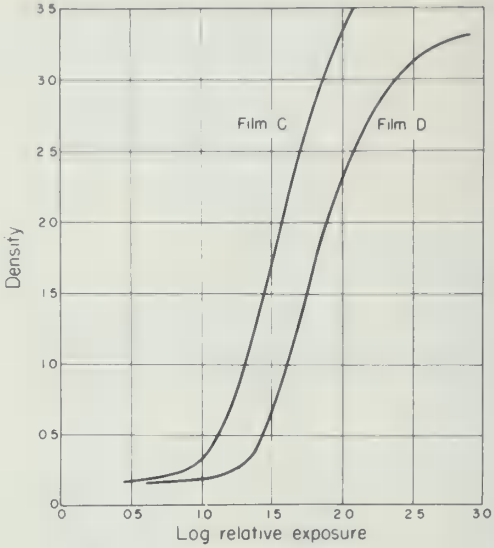


Figure 1.21. Characteristic curves of two typical medical x-ray films, one (C) being faster than the other (d). Exposures are made with calcium tungstate intensifying screens.

It is quite possible for the curves of two films to cross, as is shown for two hypothetical films in Figure 1.22. If the relative speeds of these films are calculated at a density of D_1 the low-contrast film, film B, will be judged faster since it requires the smaller exposure to reach the given density. If, however, the speeds are computed at a density D_2, the high-contrast film, film A, will be the faster of the two. Obviously, if the intermediate density, at which the two curves cross, is used in the speed evaluation, the two films will be considered of equal speed, since they require exactly the same exposure to reach the density at which their characteristic curves intersect.

Thus, a mere statement of the relative speeds of the two films is sufficient only if their characteristic curves have the same general shape. In comparing films whose average gradients differ widely, values of relative speed must be supplemented by information on the contrasts of the films and on the density at which the speed is determined.

In radiography a much more qualitative measure of film speed is often used. The relative speeds of two films are considered to depend upon the exposures which, to a particular qualified observer, result in equally satisfactory film records. This expression of speed is a subjective combination of the factors of contrast and actual film speed. Although it is used considerably in practice, it does not lend itself to mathematical evaluation and analysis, since the judgments of speed on this basis vary from observer to observer, and depend on the part radiographed and even on the viewing conditions.

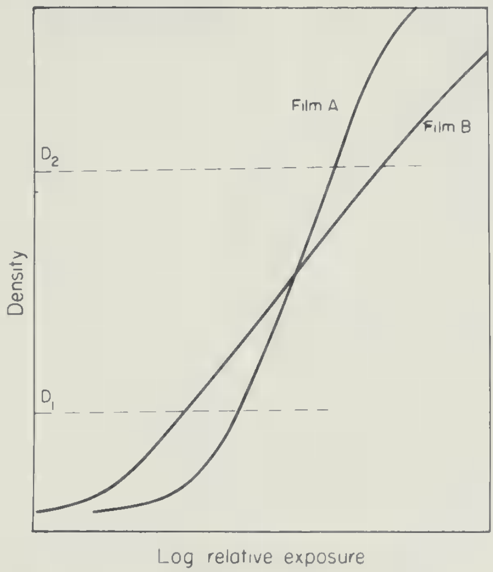


Figure 1.22. Characteristic curves of a hypothetical high-contrast film A and a low-contrast film B. The relative speeds of the two films depend on the density at which they are measured.

Use of the characteristic curve

The characteristic curve can be used in the *solution of quantitative problems* arising in radiography, in the *preparation of technique charts,* and in *radiographic research.* Ideally, characteristic curves made under the actual radiographic conditions should be used to produce characteristic curves in the individual radiographic department. But curves prepared by another organization or group may be the only curves available. Such curves will prove adequate for many purposes. However, it must be remembered that the shape of the characteristic curve and the speed of a film, relative to that of another, depend strongly on *developing conditions.* The accuracy attained when using ready-made characteristic curves will be governed largely by the similarity between the developing conditions used in producing the characteristic curve and those for the films whose densities are to be evaluated.

A few examples of the quantitative use of characteristic curves are worked out below. Typical characteristic curves of medical x-ray films are cited, to indicate the methods, which apply equally well to industrial x-ray films. Other problems, not specifically dealt with here, can be solved by similar methods.

Since logarithms are used so extensively in the mathematical work involving the characteristic curve, a brief review of some of the more important properties of logarithms will prove helpful (see above).

Example 1: Suppose a radiograph made on film B (see Figure 1.23) with an exposure of 20 Ma.S. has a density of 0.8 in the region of maximum interest. It is desired that the density be increased to 1.5 for the sake of the increased contrast available there.

Log E at $D = 1.5$ is 1.75 (1)

Log E at $D = 0.8$ is 1.54 (2)

Difference in log $E = 0.21$ (3)

The antilogarithm of this difference = 1.6.

Therefore, the original exposure should be multiplied by 1.6, giving 32 Ma.S. to produce a density of 1.5.

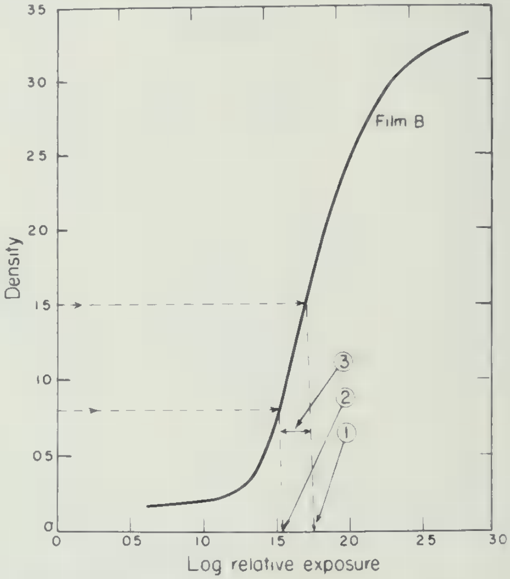


Figure 1.23. Example 1. Characteristic curve of a typical screen-type medical x-ray film, exposed with fluorescent intensifying screens.

Example 2: Suppose it is desired to make the same radiograph on film A (see Figure 1.24), with the same density of 1.5 in the region of maximum interest.

Log E at $D = 1.5$ for film B is 1.75 (4)

Log E at $D = 1.5$ for film A is 1.44 (5)

Difference in log $E = 0.31$ (6)

The antilogarithm of this difference = 2.0.

Therefore, the exposure for $D = 1.5$ on film B (32 Ma.S.) should be divided by 2.0, giving 16 milliampere-seconds, for $D = 1.5$ on film A.

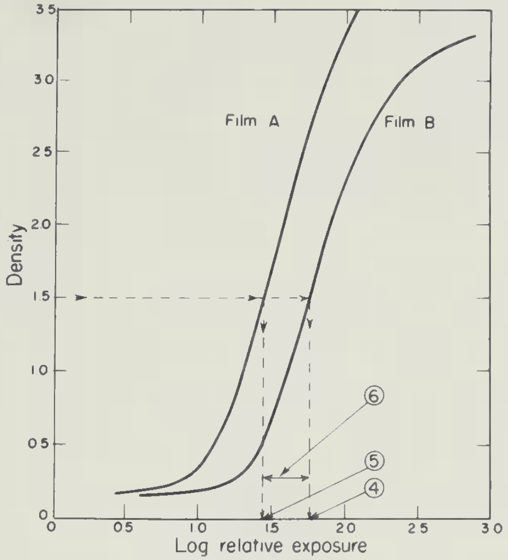
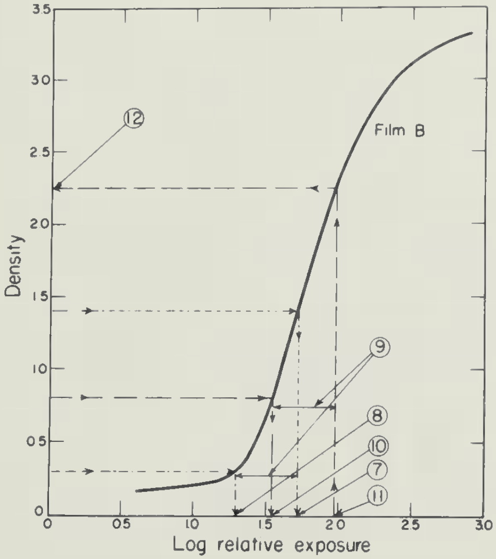


Figure 1.24. Example 2.

Example 3: Suppose a certain subject is radiographed on film B (Figure 1.25) so that the maximum density is 1.40 and the minimum density is 0.30. The slope of the characteristic curve at $D = 0.30$ is too low to give radiographic contrast adequate for the particular application and, for this reason, it is desired to increase the minimum density to 0.80. The required increase in exposure can be found by the method of Example 1 above.

Figure 1.25. Example 3.



THE LATENT IMAGE

The latent image cannot be seen or detected by any ordinary physical means, but it can be changed into a visible image by chemical processing. Many theories have been advanced as to the nature of the changes in the silver halide molecule that occur in the formation of the latent image. The generally accepted theory regarding the initial effect of x-ray exposure on the film is that a liberation of electrons occurs in the silver halide crystal. Normally, a silver halide crystal is a non-conductor of electricity. Upon exposure to x-rays or light, however, it becomes a weak conductor. From the individual atoms in the crystal, the exposure stimulus releases photoelectrons that flow within the crystal as a tiny electric current. In this movement, some of the electrons are acquired by the silver specks, which thereby assume negative electric charges. The silver halide molecule then undergoes a complicated series of internal changes. The slower-moving silver ions with a positive charge travel to the negatively charged specks, where they are neutralized to form a tiny nucleus of free silver, while the halide portions of the molecule are absorbed elsewhere. Silver ions are attracted and the speck grows larger with free silver until it reaches a size that can initiate chemical reduction of the whole crystal to metallic silver when attacked by the reducing agents in the x-ray developer solution. The exposed silver specks in their aggregate constitute the *latent image.*

Chapter 2. **CASSETTES AND SCREENS**

CASSETTES

A cassette is a thin, light-tight container slightly larger than the film it is intended to hold. The front is made of a radiolucent material such as Bakelite or Magnelite; the back is of steel or light-weight metal. Felt gaskets insure light-proof edges; and the inner, or back, side is lined with a thin layer of lead (except phototimer cassettes) to absorb secondary radiation emitted by the back of the cassette and Bucky tray or table top. A good cassette is light-proof and provides good contact over the entire area of the film. Unsharpness of the radiographic image is often due to a bent or warped cassette front and/or poor screen contact.

Phototimer cassettes

The cassettes used for conventionally timed radiography have lead-lined backs, to reduce the effect of backscattered radiation on the film. Cassettes used for phototiming must have a radiolucent back to permit the radiation reaching the film to continue on to the photo-cell, which acts as a timing device, according to a predetermined density scale. Care should be taken for appropriate identification of phototimer cassettes when both types of timing are used.

Worn felt

In many cassettes the lid felt serves a dual purpose. It affords a light-tight seal preventing the enclosed film from being light struck around the edges, which would cause fog. The felt also insures better contact. Figure 2.1 shows fog from light leak.

Poor screen contact

Poor screen contact shows on the finished radiography as poor definition or detail in certain areas. Figure 2.2 shows a radiograph with poor definition due to a warped cassette front.

Test for cassette or screen contact. Lay a wire screen (about $^3/_{16}$ inch mesh) on top of the cassette to be tested. Make an exposure at about 50 Kv.P., $^1/_{20}$ second, 50 Ma., 36-inch focus-film distance. Develop the film in the usual manner. If the film shows blurred outlines or is fuzzy, probably the contact is poor between screens and film. It is wise to check the front of the cassette before removing the screens since it may be warped, or the back of the cassette may be sprung at the hinged area because the cassette has been dropped. Figure 2.3 shows poor contact due to a warped front. Figure 2.4

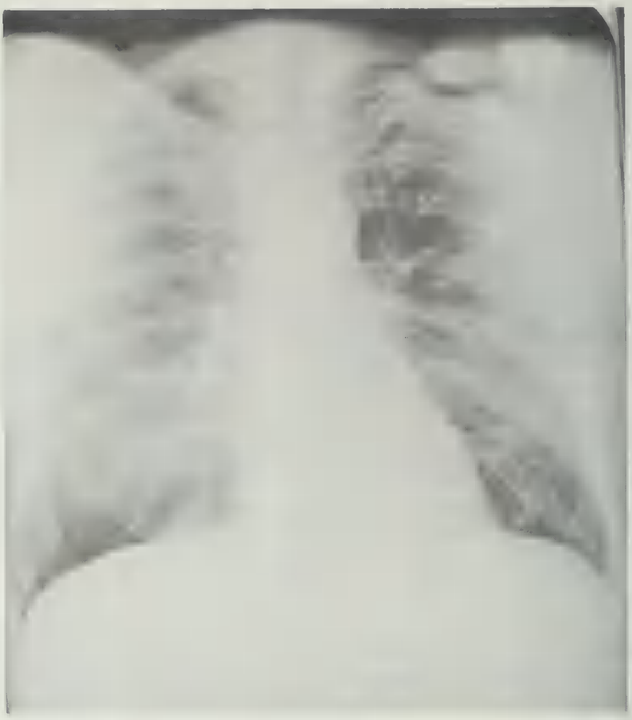


Figure 2.1. Fog caused by light leak.

shows the same cassette after repairs, which resulted in a saving of some $50.00, since the screens did not have to be replaced. It is false economy to mount new screens in faulty cassettes. Other cassette faults which affect film quality include worn felt, loose hinges, dented fronts, or sprung frames. Although cassettes are sturdy and strong enough to withstand normal hard usage, they cannot withstand abuse.

RADIOGRAPHIC CALIBRATIONS

The formulation of techniques is extremely difficult, if not impossible, when one is faced with a radiographic machine that has not been calibrated properly. It is ideal, indeed, to formulate techniques on one unit and then transpose the techniques to other units within the same department. Each radiographic unit should be calibrated, and in turn each unit should have equal densities on a film when identical exposures are made.

Inaccuracy of equipment means repeat films, unnecessary exposure to the patient, decreased efficiency of the department, and waste of film.

Each radiographic unit should be calibrated by a service engineer; however, the radiologic technologist should be responsible for the exposure factors, processing, proper cassettes, and film.

The timer should be checked with a spinning top for exposures of less than 1 second and with a stop watch for exposures longer than 1 second.

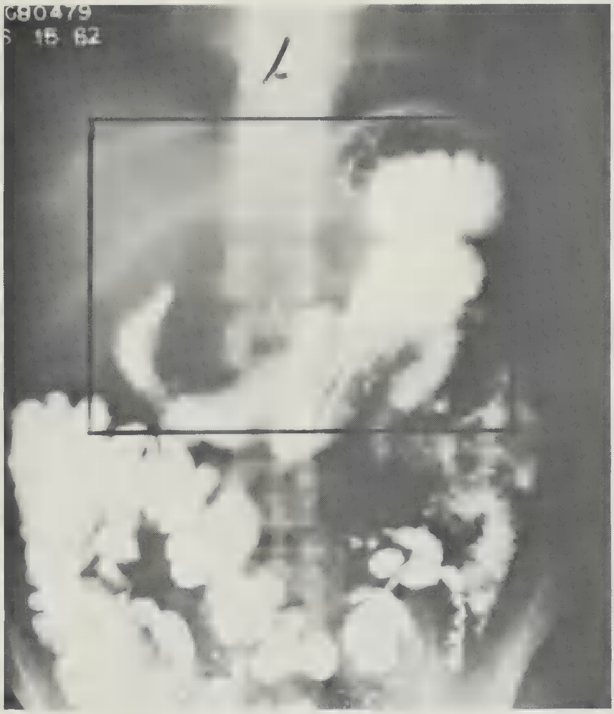


Figure 2.2. Poor definition due to a warped cassette front.

ure 2 3. The result of poor screen contact due to arped cassette front.

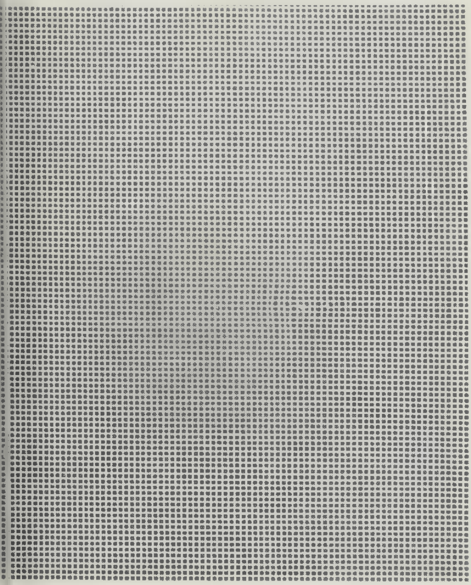
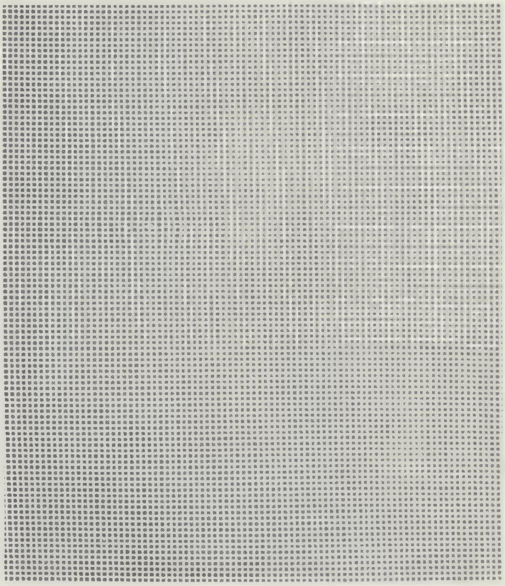


Figure 2.4. The cassette of Figure 2.3 has been repaired, and this is the result.



With a *three-phase unit*, one should use an oscilloscope in place of a spinning top to check the timer for accuracy.

No matter what Ma. station and time-increment values are used, as long as the product is the same, the density level should remain the same.

Example: 100 Ma. at $^{1}/_{10}$ second, 200 Ma. at $^{1}/_{20}$ second, and 300 Ma. at $^{1}/_{30}$ second should all produce the same density.

Figure 2.5 shows a radiograph made with a machine properly calibrated. Figure 2.6 shows a radiograph with the same exposure, but made with a unit that was out of calibration.

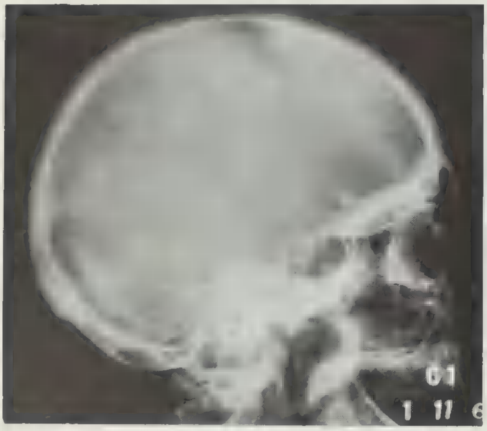


Figure 2.5. This radiograph was made with a properly calibrated machine.

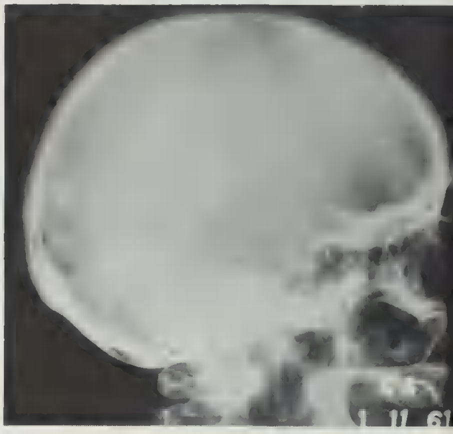


Figure 2.6. This radiograph was made with a mach
out of calibration.

INTENSIFYING SCREENS

Certain *intensifying screens* are used in medical radiography to intensify the effect of x-rays. The screens emit a blue light when excited by x-rays, and x-ray film is especially sensitive to blue light. Less than 5 per cent of the density on a radiograph is caused by the direct action of x-rays. More than 95 per cent of the film density is due to the light given off by the intensifying screen.

The use of screens not only reduces the radiographic exposure time and dosage factor, but adds materially to the contrast of the resultant radiograph.

Certain chemicals have the ability to absorb x-rays and instantaneously emit light. This property is called *fluorescence*. The compound that is most commonly employed in intensifying screens is a white crystalline salt, *calcium tungstate,* because of its effectiveness as a fluorescent agent.

At the present time there are three general classes of screens, based largely upon application and speed. The most widely used screen is the *medium speed*. Each manufacturer has his own trade name for screen speed. Generally, the medium-speed screen possesses the best balance between *speed* and *detail* for most radiographic purposes.

With the increased interest in radiation dosage, the *high-speed* screen has become very popular; however, there is a slight loss in detail of the radiographic image. There are many situations in which high-speed screens are very valuable and the slight loss of detail is of very little diagnostic significance. The most common of these are

1. Where reduction of radiation dosage is important.
2. In portable bedside and operating-room radiography where there is a limit on kilovolts and milliamperage.
3. In grid cassettes.
4. In high-kilovoltage radiography.
5. In the radiography of infants and children.
6. In spot-film radiography.

Slow-speed screens render better detail and are used for bone radiography, magnification techniques, and where speed is not at a premium.

Multisection screen books for use in body-section radiography represent a special application of intensifying screens: With the multisection screen book, up to seven layers of a body part can be radiographed simultaneously. Each screen pair is balanced in speed to yield the same exposure density on each film.

The DuPont Company has announced a 14 x 36 Gradient Intensifying Screen which has proved to be advantageous for venograms, femoral arteriograms, leg-length measurements, and radiography of the entire spine. A screen of this type eliminates the need for wedge filters by employing different screen speeds to produce uniform densities of the body parts being radiographed.

The Dupont barium–lead sulfate Hi-Speed screens emit more fluorescence in relation to crystal size than does calcium tungstate. Consequently, it has been possible to produce a fast, high-quality screen of uniformly fine grain.

Stains and abrasions

The most common stains on screens are caused by careless processing-room technique. Developer or hypo smears will stain screens a brownish color and will result in light areas on the finished radiograph. Dust and other foreign materials sometimes get into the cassette and will cause damage to screens. Routine periodical cleaning of screens with soap and water or 95-per-cent alcohol is recommended.

Various commercial screen cleaners are now available from your x-ray dealer.

Test for lag

Intensifying screens must not continue to fluoresce after the exposure has been terminated; continued fluorescence of screens is called *lag*. Lag will cause a general fogging of the radiographic image and appear as though it might be from secondary radiation or from postexposure fog. Lag is generally due to old, worn-out screens.

To test screens for lag, make a normal exposure of some part with the cassette *empty* of any film; take the cassette to the processing room and place a film in it; close the cassette and allow the film to remain in the cassette for five minutes; then develop the film in the same manner as a normally exposed radiograph. If the image of the part exposed is imparted to the film, then the screens have lag, which produces a supplementary density.

Chapter 3. **PROCESSING**

THE PROCESSING ROOM

In our experience the processing room is the most important single room in the department of radiology, yet it is the one room most often neglected by both radiologic technologists and radiologists. A technologist can never hope to be a really good technologist unless he is *master* of the darkroom and processing technique. The best and most expensive radiographic equipment is of no avail if one tolerates carelessness or does not have a rigid time-temperature developing routine set up for processing x-ray films. The processing room can make or break a department as far as quality of radiographic films is concerned.

Because of the special importance of this room in the handling, processing, and even flow of work, both the general and detailed features should be most thoughtfully worked out.

Arrangement of equipment

The three major elements of equipment—loading bench, processing tanks, and dryer—should be arranged so that the number of steps taken can be kept at a minimum. Automatic processing has eliminated many of the problems heretofore encountered.

Light-tight entrance

An entrance that is easily accessible while providing complete protection from outside white light is an essential to the x-ray processing room.

Ventilation

Satisfactory ventilation of an x-ray processing room requires more consideration than the ventilation of other rooms. The processing room contains certain elements that directly affect the air in it. If hand processing is used, open tanks of developer, acetic-acid solution, and water increase the humidity and create slight odors. Automatic processing eliminates the problems of humidity and chemical odor.

When improperly controlled, the temperature and humidity of the air have adverse physiological effects on the technologist as well as physical effects on film handling and storage. For example, excessive humidity causes the body to perspire, and damp fingers readily mark dry films and screens. If the air is too dry, film is susceptible to static accumulations.

Color

It is not necessary for the processing room to be a drab, all black room.

It is neither necessary from a technical standpoint nor desirable from a psychological one. If the *quality* of the light from a safelight lamp is *safe*, the illumination from any surface is also "safe" regardless of color.

The best processing room illumination is that transmitted by a Kodak Safelight Filter, Wratten Series 6-B, using a 10-watt tungsten light source.* The light transmitted is in the yellow and yellow-red portion of the spectrum. Therefore, maximum reflection under safelight illumination is achieved if the wall finish is either a color within this same spectral range or a light enough shade of any other color.

The color of the loading-bench top should be chosen with the thought that film, interleaving paper, and other objects must be readily distinguished.

One of the most durable materials used for the loading-bench top is sheet plastic.

Figure 3.1. Postexposure fog: the lighter portion of this radiograph was protected by a sheet of cardboard during the safelight test which fogged the rest of the film.

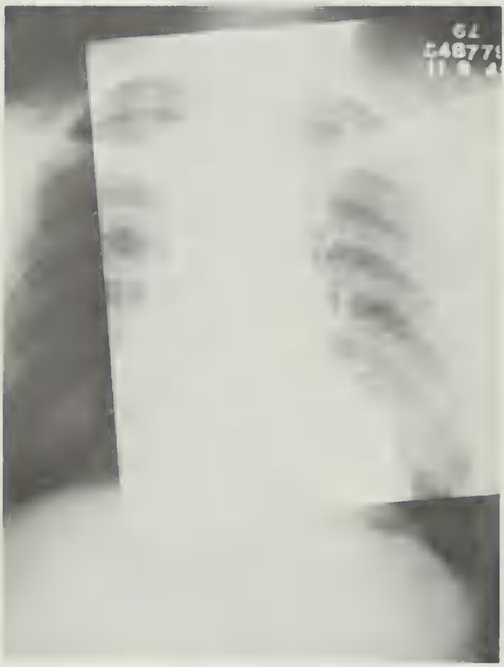
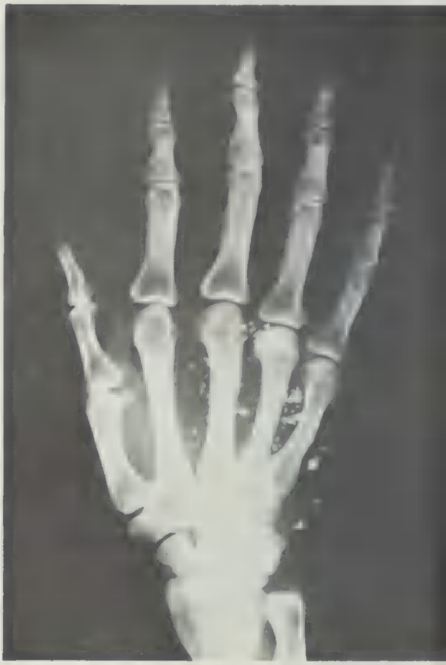


Figure 3.2. Cigarette ashes in the cassette.



Effect of safelight illumination

With present-day safelights (Wratten 6-B), it is possible to see clearly in the processing room. When the safelight lamps are fitted with a 10-watt bulb and a filter recommended for the light-sensitive film being used, the exposed films can be exposed, without fogging, for one minute at three feet from the safelight, or for one-half minute at two feet.

Exposed radiographic films are more sensitive to safelight illumination than unexposed films, in fact, *eight times more sensitive* to fog than are unexposed films.

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*Directly over the manual processing tank.

The effect on x-ray film of exposure to the illumination from safelight lamps is referred to as *postexposure.*

The quality of a radiograph may be impaired by unnecessary exposure to safelight illumination, which is the reason for variations in density encountered in routine radiographs and for the lack of brilliancy that is frequently attributed to scattered radiation.

With respect to films exposed to *direct x-radiation* (exposed with a cardboard holder), the effect is very slight and may be disregarded. This is largely true, also, with respect to films that have received relatively heavy x-ray exposures employing calcium tungstate intensifying screens, although radiographic contrast is slightly impaired. However, in radiography of light density, as of the chest or gallbladder, the radiographic contrast may be seriously affected.

When radiographs have been *unprotected* from postexposure and we begin to protect them from postexposure, the contrast will increase to such a degree as to permit an increase in exposure thereafter.

To eliminate undesirable postexposure, we may reduce the intensity of the safelight illumination in one of three ways: (1) by employing bulbs of lower wattage; (2) by increasing the distance between the safelight lamps and the top of the film-loading bench; (3) by reducing the number of safelight lamps.

Films exposed with screens should be protected from direct light of safelight lamps. When exposed films are being placed in the developing hangers, the loaded hangers should be set to one side, away from the lamps, or placed behind a protective screen until ready to be placed into the developer solution.

Safelight test. In testing a darkroom light for safety, one should subject part of an exposed x-ray film to the illumination of the safelights under the conditions used during normal processing and compare with a portion similarly exposed to x-rays but developed in total darkness.

Cleanliness

Owing to the sensitivity of x-ray film emulsions, cleanliness is essential in processing procedures. It is imperative that the processing room, as well as the accessories and equipment, be kept scrupulously clean. Solutions that are spilled should be wiped up at once; otherwise, upon evaporation, the chemicals may get into the air and later settle on film surfaces, causing spots.

Films should be handled with care in the processing room, as permitting them to become wrinkled or bent will result in small marks called "crinkle marks." Rubbing films together before processing will cause static marks resembling the branch of a tree. If two films come in contact with each other during the developing process, an area of nondevelopment will appear in the area of film contact. This also occurs if the film is allowed to touch the side of the developing tank.

Excessive exposure of a film to light during development may result in

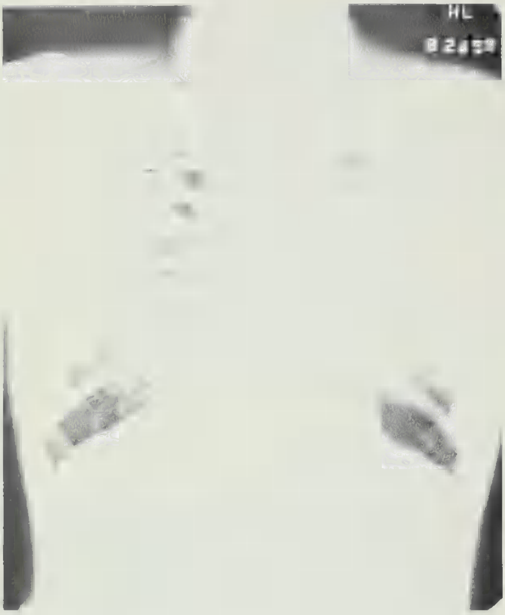


Figure 3.3. Crinkle marks due to bending of the film before exposure.

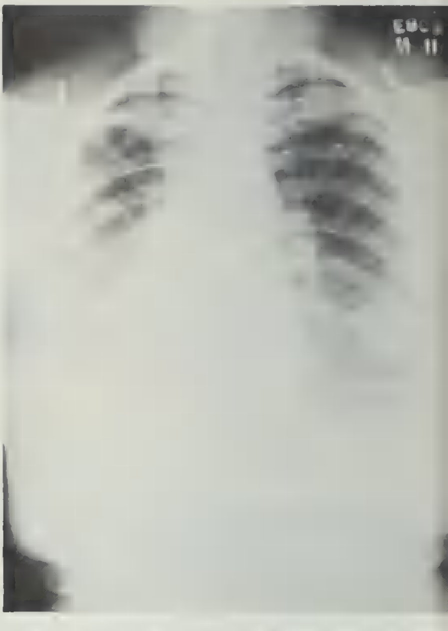


Figure 3.4 Area of underdevelopment that resulted from contact with another film during velopment.

reversal of the image; in other words, the "blacks" will be white and the "whites" will be black. A greasy appearance on the surface of the film is due to improper washing after fixing.

THE PROCESSING HANGER

The processing hanger provides a means for securely holding the film during the processing routine. The developing hanger should be made of stainless steel.

Hanger adjustment

Bow springs of hangers which have been used for an extended period gradually lose their original tension and, instead of producing tautness in the films, permit them to bulge. When several hangers exhibiting this deficiency are placed in the processing tank, areas of the films they hold may touch or even adhere to each other, preventing complete development and resulting in artifacts in the radiographs.

To correct the condition, the springs may be bent until the distance between opposite top and bottom clips, when not supporting a film, is slightly greater than the length of the film intended to be hung in the space. This can be readily accomplished by the following procedure. Place the hanger on the loading bench. Insert in the jaws of the lower clips a sheet of cardboard from a box of x-ray film of the same size as the hanger. Bend the bow springs upward until the lower tips of the clips attached to them are about 1/8 inch above the top edge of the cardboard. When this adjustment has been made, films which are placed in the hanger will again be held taut.

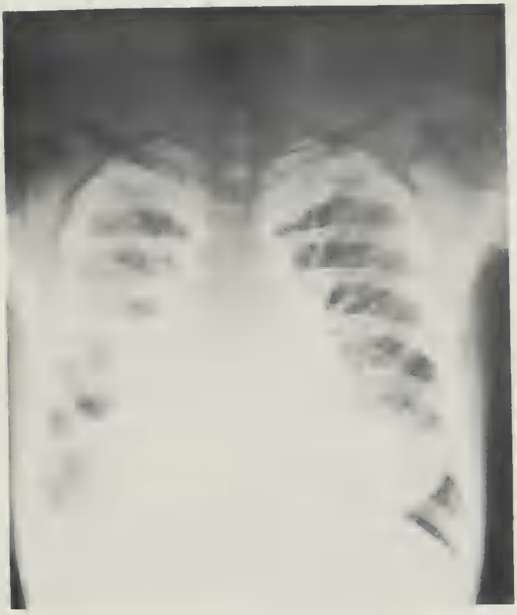
Cleaning film hangers and clips

Metal film hangers and clips tend to accumulate a plating of silver when immersed in a fixing bath which contains dissolved silver salts. Such deposits are often of a spongy nature and may be mixed with gelatin and other substances. These deposits absorb chemicals from the processing solutions which are not removed by ordinary washing, and when the hangers are re-immersed in the developer, some of these chemicals may leak out and cause fog on the film.

There are three methods of removing such deposits, and the choice of method will depend on the severity of the conditions. The acetic acid treatment is the simplest; boiling with trisodium phosphate, however, will be more effective in the majority of cases. Tray cleaner should be used with caution on metal equipment.

Acetic acid treatment. Soak the hangers or clips for an hour in a tray filled with 10-per-cent acetic acid solution (1 part glacial acetic acid to 9 parts of water, or 1 part 28-per-cent acetic acid to 2 parts of water). The acid tends to loosen the deposit. Then wash with clear water and scrub the deposit with a stiff brush. Most deposits can be loosened and removed by this treatment.

Figure 3.5. Reversal action.



Trisodium phosphate treatment. Boil the equipment for several minutes in a 10-per-cent solution of trisodium phosphate; then wash it with water and scrub thoroughly with a stiff brush. This method is especially useful for cleaning deposits of spongy silver mixed with gelatin. This method should not be used for aluminum ware.

Acid bichromate treatment. If the silver deposit clings tenaciously to the metal hangers, it may be necessary to dissolve it with Kodak Tray Cleaner TC-1, diluted 1 part TC-1 to 2 parts of water.

PROCESSING

As stated previously, the greatest error in the production of the radiograph often may be a flagrant disregard for the simplest of processing rules; therefore, knowledge concerning the proper handling and care of x-ray films and their correct processing should be of primary importance to every radiologic technologist.

Mixing solution

The first step in the processing procedure is the proper preparation of the developer and fixer solutions. When mixing the chemicals it is imperative that the technologist follow the manufacturers' directions found on the label of the container to obtain the best results. There are, however, some general recommendations which it is necessary to observe when mixing solutions. The successful operation of the processing room will depend upon observing the following rules:

1. The temperature of the water in which the chemicals are to be dissolved should never exceed that shown on the label of the package.
2. The containers for mixing the chemicals should be made of corrosive-resistant materials, such as good enamel or glazed earthenware, glass, hard-rubber, or Type 316 stainless steel. Vessels made of tin, copper, zinc, aluminum, or galvanized iron should be avoided.
3. The water should always be poured into the tank or pail, and the chemicals added slowly while the mixture is stirred vigorously, permitting the chemicals to go into solution quickly without lumping.
4. When the chemicals are entirely dissolved, sufficient cold water should be added to bring the solution to the correct volume and temperature; thorough stirring is necessary to mix the cool water with the chemically laden solution already present. Solutions should never be used until all the chemicals are thoroughly dissolved and the correct temperature (generally 68° F.) is maintained.
5. Separate paddles for the developer and for the fixer should be employed for mixing purposes. Afterwards they should be washed with clear water and hung up to dry. Stainless steel paddles or hard-rubber paddles are preferred.
6. Processing tanks should be thoroughly scrubbed and cleaned before fresh solutions are placed in them.
7. The developer tanks should be fitted with a cover to reduce the amount of air in contact with the solutions, thereby lessening the effects of aerial oxidation when not in use.

THE DEVELOPER

Basic constituents (manual processing)

There are four basic constituents in a developer:

1. Developing agent
2. Accelerator
3. Preservative
4. Restrainer

The proposition and kind of ingredients used depend on the specific purpose for which the developers are compounded.

The *developing agent* serves to convert the silver halide of the *invisible latent image,* produced by x-rays, light, or other forms of radiation, into a visible image composed of minute grains of metallic silver. In radiographic developers two organic developing agents are commonly used in combination: Elon and hydroquinone. Each of these chemicals behaves differently as a developing agent. Elon begins development within a few seconds and the entire image appears rapidly. Fine detail is produced in the image but the contrast is low. The initial action of hydroquinone is somewhat slower than that of Elon. The most exposed portions of the latent image are acted upon first and become quite dense before the less exposed areas are developed. The effect of hydroquinone is the production of an image of suitable contrast. The combination of the two agents thus serves to provide an acceptable radiographic image with good detail and moderate to high contrast.

These developing agents are rendered effectively active only after an *accelerator*—an alkali—has been included in the developer.

Because alkaline developer solutions are rapidly oxidized by air, an antioxidant *preservative,* such as *sodium sulfite,* is included. Were the preserv-

Table 3.1 X-RAY DEVELOPER

Chemical	*General function*	*Specific function*	
Elon	Developing or reducing agents	Builds up detail quickly in first half of development period.	Developing agents reduce exposed silver bromide crystals emulsion to black metallic silver constituting the image
Hydroquinone		Builds up contrast slowly during development period	
Sodium sulfite	Preservative	Prevents rapid oxidation of developer	
Sodium carbonate	Alkali or Activator	Governs reducing activities of developing agents; provides necessary alkaline medium and swells gelatin emulsion so that reducing agents can attack exposed silver bromide crystals	
Potassium bromide	Restrainer	Controls activity of reducing agents and tends to prevent fog	

ative not present, the developer solution would oxidize with great rapidity even when not in use.

In order to control or limit the action of the developing agent so that it does not develop the unexposed silver halide to produce fog, *restrainers* such as *potassium bromide, potassium iodide,* and various organic compounds are added. Developers may also contain other substances, often in very small quantities, which improve the physical properties, increase activity and life, and reduce sludging.

Degree of development

No visible image is present on the exposed film when it is immersed in the developer. The image appears after a few seconds, first in the area which received the most exposure. As development progresses the lesser-exposed areas begin to appear, and the contrast of the image builds up. With 3-minute development, nearly full contrast is obtained, and the film requires only half the exposure necessary with 2-minute development. With 5-minute development, the film speed is about 35 per cent more than is obtained with 3-minute development and the contrast is substantially the same. Only a third of the original exposure is needed to produce the desired density.

This emphasizes the importance of the degree of development in relation to film speed—a factor that is not always fully appreciated by the radiologic technologist.

The first three radiographs shown in Figure 3.6 were made with the same exposure of 5 Ma.S. In radiograph A, which was developed for 2 minutes at 68° F., detail is lacking in the image and contrast is low. In radiograph B, which was developed for 3 minutes, detail and contrast are improved, but it is only in radiograph C, developed for 5 minutes, that optimum film speed is obtained. It can be seen, too, that radiograph D, which received only 3-minute development, also possesses satisfactory radiographic quality. This was achieved by employing an exposure of 6.5 Ma.S., which is 30 per cent more than was used to obtain radiographs A, B, and C. Therefore, in routine radiographic work, the factors of exposure and development are interchangeable during the developing time interval between 3 and 5 minutes. However, the gain in film speed achieved by 5-minute development provides one important advantage over the 3-minute time. It permits the employment of the shortest practical exposure for each radiograph; thus involuntary movement of the patient or organ is minimized, and the life of the x-ray tube may be lengthened. Figure 3.7 is a radiograph of the chest made at 10 Ma.S. and processed for 3 min. Figure 3.8 is the same chest at 7.5 Ma.S. and 5 min. developing.

Development by inspection

The foregoing discussion assumes that the technologist should adopt a time-temperature processing procedure based on either 3- or 5-minute development at 68° F. However, since a presentable radiograph can be produced in any developing time between 3 and 5 minutes, it is evident that visual inspection of the film could be employed to compensate for errors in exposure. The effects of overexposure which might be brought about by

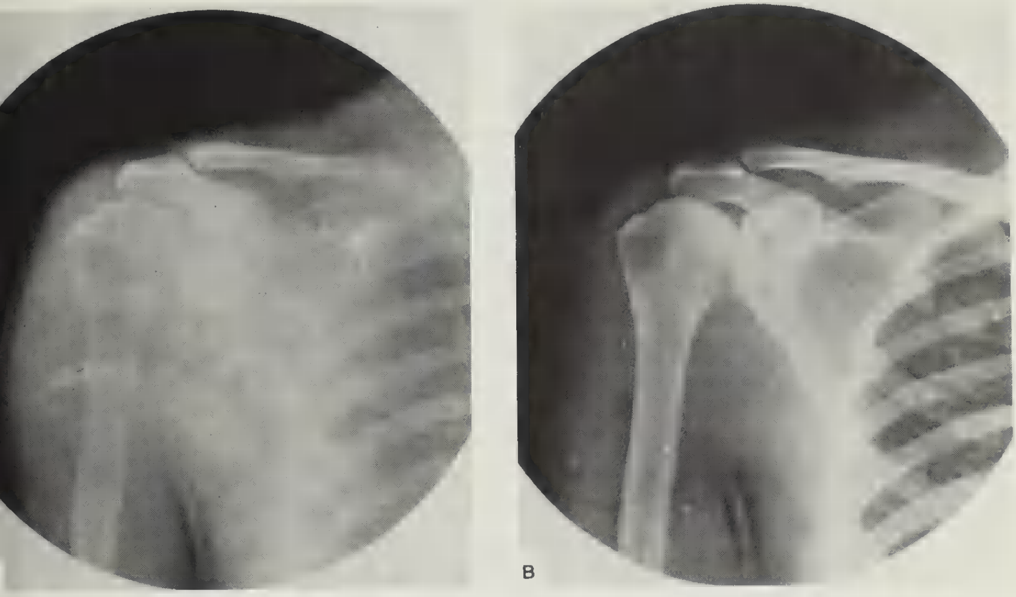
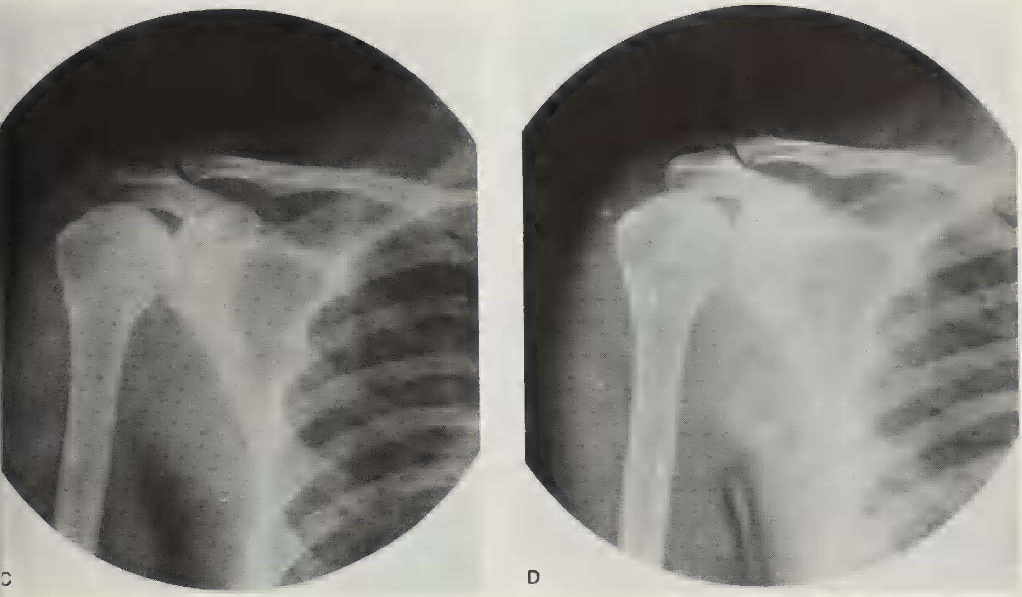


Figure 3.6. The effect of the time of development on the visual quality of the radiographic image. Radiographs A, B, and C received 5 Ma.S. exposure. The kilovoltage was 60; the distance 40 inches. The radiographs were developed in Kodak Rapid X-Ray Developer at 68°F. with intermittent agitation, and with times of development as follows: A, 2 minutes; B, 3 minutes; C, 5 minutes. Radiograph D received 6.5 Ma.S. exposure (a 30 per cent increase over A, B, and C). The time of development was 3 minutes. All other factors were the same as for radiographs A, B, and C.



5-minute development could possibly be precluded by developing for a shorter time as indicated by inspection. If, however, a film shows effects of underexposure when developed for 3 minutes, it may possibly be salvaged by prolonging the developing time to 5 or 6 minutes. Such a procedure is used with some degree of success in many departments by technologists whose judgment is based on considerable experience and who can take the necessary time. However, it is usually found that the errors in judgment introduced as a result of variations in eye accommodation, of the low level

Table 3.2 DEVELOPMENT TIME CHART

Kodak medical x-ray film (blue brand)—Replenisher method five-minute development

For maximum speed and contrast—5 minutes at 68°		*For normal speed and contrast—3 minutes at 68°*	
Temperature	*Time*	*Temperature*	*Time*
60° F.	8½ Min.	60° F.	5 Min.
60° F.	6¾ Min.	62° F.	4½ Min.
64° F.	6¼ Min.	64° F.	4 Min.
66° F.	5½ Min.	66° F.	3½ Min.
68° F.	5 Min.	68° F.	3 Min.
70° F.	4½ Min.	70° F.	2½ Min.
72° F.	4¼ Min.	72° F.	2¼ Min.
74° F.	3¾ Min.	74° F.	2 Min.
75° F.	3½ Min.	75° F.	1¾ Min.

Note: A Kodak Development Time Indicator may be secured, free on request, by writing the Medical Technical Service, Eastman Kodak Co., Rochester, N. Y.

Figure 3.7. Radiograph of chest made at 10 Ma.S. and processed for 3 minutes.

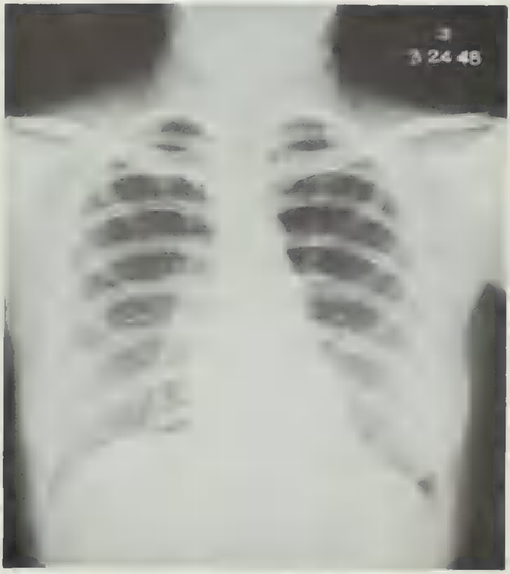
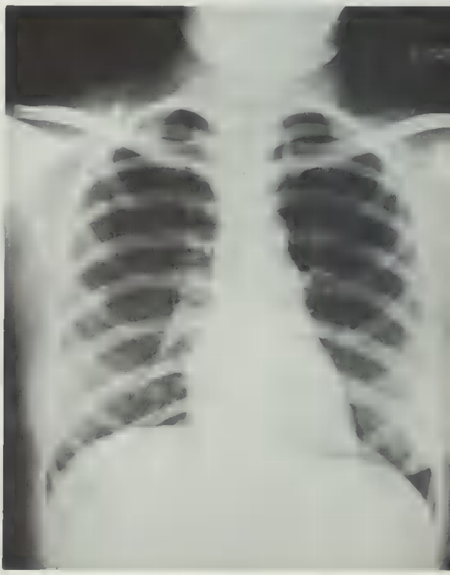


Figure 3.8. Radiograph of the chest of Figure made at 7.5 Ma.S. and processed for 5 minutes.



of illumination, and of the opacity of the uncleared film are greater by far than the errors initially made in exposure. Therefore, exercise of good judgment in making the exposure, and the use of tested exposure charts and the time-temperature method of processing are the optimum procedures for routinely producing radiographs of suitable and uniform quality.

Temperature of developer solution

The rate of development is affected by the temperature of the solution. Development proceeds more rapidly at higher temperatures and more slowly at lower temperatures; within limits, changes in the rate of development can be compensated for by varying the development time. The range of temperature of the developer solution recommended for x-ray films is from 60° to 75° F.

Agitation

As the film develops and the exposed silver bromide is reduced to metallic silver, bromide ions and other products of development are released from the emulsion. These reaction products exert a restraining influence on further development, an effect that is increased as the concentration of active developing agents is lowered. Agitation replaces the exhausted developer at the surface of the film with fresh solution and tends to overcome the restraining action. Agitation may consist of raising and lowering the film about 2 inches continuously during development. The effect of agitation is equivalent to approximately a 20-per-cent increase in developing time if done in this manner.

Another important effect of agitation is the prevention of uneven development, or mottle. If films are placed in a developer solution and allowed to develop without any movement, there is a tendency for each area of the film to affect the development of the areas immediately below it. This arises from the fact that the reaction products of development have a higher specific gravity than the developer; and, as these products diffuse out of the emulsion layer, they flow downward over the film surface and retard the development of the areas over which they pass. The greater the film density from which the reaction products flow, the greater is the restraining action upon the development of lower portions of the film. Thus, large lateral variations in film density will cause uneven development in the areas below, and this may show up in the form of streaks.

Since the degree of agitation has an influence upon the rate of development, the technique chart should include a statement about agitation—whether it is continuous, intermittent, or not employed. For practical purposes, intermittent agitation is recommended. The technique for intermittent agitation is relatively simple. Start the timing. Assemble the hangers and lower them, as a unit, smoothly and carefully into the developer. Immediately tap the crossbars of the hangers two or three times on the upper edge of the tank to dislodge any air bells clinging to the emulsions. Then separate the hangers, leaving about equal spacings of at least $^3/_4$ inch between them. Allow the hangers to remain undisturbed for 1 minute. Then lift them clear of the solution; drain 1 to 2 seconds from one corner; replace smoothly in the solution and separate them. Repeat at 1-minute intervals.

Activity of the developer solution

The rate of development is affected also by the chemical activity of the developer solution. This activity, in turn, is determined by the ingredients of the developer, the dilution of the solution, and the degree of its exhaustion.

Dilution

When the developer solution is being prepared, it is important not to dilute the developer more than is recommended by the manufacturer. Many insert tanks employed in x-ray processing units have an actual capacity in excess of their rated approximate volume. Among the smaller tanks, many have a capacity of more than their rated five gallons, and some actually hold six gallons of solution. Nevertheless, powder or liquid sufficient to prepare only five gallons of solution is too often employed in such tanks. It is obvious, therefore, that if only enough developer to make five gallons of solution is mixed with sufficient water to make six gallons of solution, the fresh developer solution is 20 per cent weaker than it should be.

It is equally bad practice to restore the level of the solution by the simple addition of water. The combined effects of exhaustion and dilution cause a 10-per-cent loss of activity after development of the equivalent of fifty 14 x 17-inch films in six gallons of solution, and a 20-per-cent loss after development of the equivalent of ninety 14 × 17-inch films. The developing agent is oxidized; acid substances are released, the alkalinity of the developer is therefore reduced; and bromide ions accumulate in the solution. These changes tend to decrease the activity of the developer. There may also be aerial oxidation with alkaline side reactions, accumulation of insoluble matter and sludge formation, and other secondary changes of a mechanical or chemical nature. The extent of this decrease in activity will depend on the number of films processed and their average density. Even when the developer is not used, its activity may decrease slowly because of aerial oxidation of the developing agent.

Practical control of exhaustion

Although radiographic developers possess considerable reducing power and reserve capacity, their activity is gradually lost by exhaustion. As the degree of development is decreased, some means must be used to compensate for it if uniform radiographic results are to be obtained over a period of time. Two methods are available for such correction: (1) the *exhaustion method,* in which the activity of the solution is allowed to diminish gradually and constant radiographic density is maintained by gradually increasing the development time; (2) the *replenishment method,* in which the activity of the solution is not allowed to diminish but is maintained by suitable chemical replenishment.

Exhaustion method. It has already been pointed out that the longer the time of development the greater the degree of development. This fact is the basis for maintaining relatively uniform radiographic density throughout the useful life of the solution by increasing the time proportionately as developer activity diminishes.

In the exhaustion method it is common practice, in removing the films from the developer solution, to let the excess developer on the film drain back into the tank. Even with this procedure, each 14 x 17-inch film carries with it about $1\frac{1}{2}$ to $2\frac{1}{2}$ ounces of solution; and, in time, the level falls below the top edge of the film. When the exhaustion method is used, it is essential that *fresh developer* be added to maintain the solution level. As has been pointed out in the discussion on dilution, water must never be used for this purpose.

When fresh developer solution *of the same kind* is added to restore the level of the original solution, the activity of the developer is revived somewhat but never sufficiently to overcome the deleterious effects of accumulated bromide, oxidized developing agents, and reduced alkalinity.

Replenishment method. The use of a replenisher solution to replace the developer carried out by the films automatically compensates the gradual loss of developer activity. The replenisher solution is designed to keep the activity of the developer constant when added at the correct rate. Since the replenisher, rather than the developer, carries the load, its composition is important. It differs from the original developer in that it is a much more powerful reducing solution. It contains a greater quantity of developing agents to replace those used. It has a high alkalinity to compensate the reduced alkalinity of the original solution and to overcome the restraining action of the accumulated bromide.

When properly employed, the replenisher effectively maintains the activity of the developer solution, and little difference may be seen in the relative densities of the first and last films developed during the useful life of a replenished solution.

Technique of replenishment

When added to the developer solution at the proper rate, replenishers will maintain the properties of the developers effectively during their useful life. The rate of replenishment depends on the degree of exhaustion determined by the density of the films developed, the type of film used, and the amount of solution carried out. The higher the density of the film, the more silver there is to be reduced, and the greater the amount of work that must be done by the developer. Consequently, if dense radiographs are routinely produced, more replenisher should be added than for radiographs of medium or low density. With respect to type of film used, non-screen x-ray film, because of its thicker emulsion, exhausts the developer more rapidly than does regular x-ray film. Thus, when a high proportion—for example, 25 per cent—of non-screen film is processed, somewhat more replenisher must be added than when only a small quantity is developed.

The quantity of developer carried out by the film depends on the degree of swelling of the emulsion and on the draining time. A 14 x 17-inch film absorbs approximately $1\frac{1}{4}$ ounces of developer, and when lifted out of the developer, and before drainage, has enough additional developer adhering to the film surface to total about 3 ounces. The greatest amount of drainage takes place during the first 5 seconds—*the critical period* in determining the success of replenishment. Therefore, in order to carry out from $2\frac{1}{2}$ to 3 ounces per 14 x 17-inch film, it is important that x-ray films have little or no draining when the replenishment method of development is employed.

To maintain a constant activity of the developer solution, the following simple procedure is recommended for routine medical radiographic processing. The film is withdrawn rapidly and smoothly from the developer solution without permitting the solution that clings to the surfaces of the films to drain back into the tank. The film is then immersed smoothly and with agitation into the rinse bath. With this technique, approximately 2½ to 3 ounces of developer solution are withdrawn with each 14 x 17-inch film. It is then necessary to add replenisher solution only periodically, in sufficient quantity to maintain the level of the solution above the top edge of the film. If, however, a relatively high percentage of very dense radiographs or of radiographs made on non-screen x-ray film is being processed, simple maintenance of level may not be enough to provide suitable activity of the replenished solution. In this situation, the quantity of replenisher per 14 x 17-inch film should be increased to 4 ounces. To accommodate this amount an extra ounce of developer solution, in addition to the 2½ to 3 ounces carried out on each 14 x 17-inch film, must be dipped out of the tank. In order to prolong the life of an acid stop bath, if one is employed, the film should be drained in the space between the tanks for 2 to 3 seconds before immersing it in the stop bath.

The replenishment procedure is facilitated if a large quantity of replenisher solution is mixed and stored in 1- or 5-gallon bottles. A bottle or two are kept near the developer tank, and a little replenisher is added every time the solution level falls an inch or so. The developer solution is then stirred well to make it uniform. Stirring is essential after adding the replenisher, as the solution may otherwise consist of layers of varying activity.

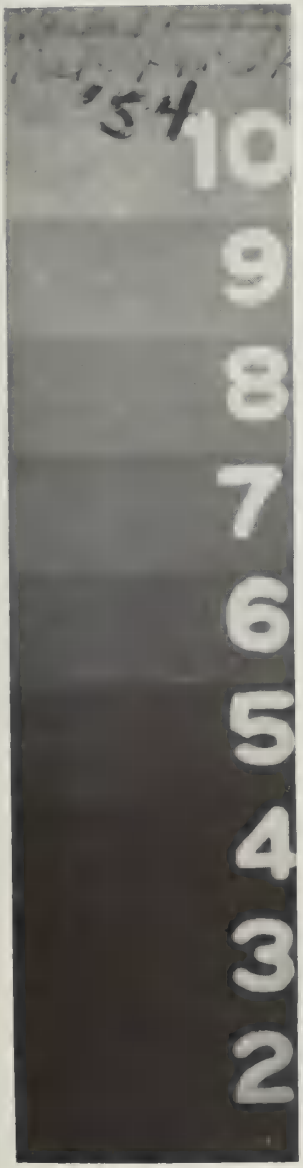
When to discard. The substantially constant properties of replenished radiographic developers give rise to the problem of when to discard the solution. For a number of reasons the useful limit of activity has been set at the equivalent of 125 14 x 17-inch films per gallon, or 750 per 6 gallons. These reasons include the accumulation of gelatin, sludge, and mechanical impurities which find their way into a developer solution; the chance of chemical contaminants, such as fixer chemicals, being carried in by the hangers; and the aggregation of small errors in replenishment which could eventually cause the activity of the developer to vary markedly from that of the fresh solution.

Even if a relatively small volume of film is developed and the developer has not been exhausted to the above degree in three months, it should be discarded because of the deleterious effects likely to result from aerial oxidation and the growth of micro-organisms.

Another useful criterion for replacement of the developer, when the number of films developed cannot be counted, is to change to a fresh solution after about 3 volumes of replenisher have been added for each volume of developer. Thus, the operator who possesses a 6-gallon tank would purchase enough to make 6 gallons of developer and 18 gallons of replenisher. When all the replenisher had been used, he would empty and scrub his tank and refill it with fresh developer.

This value, *three*, for the relation of replenisher volume to developer is a compromise, but experience indicates that it is to be recommended for use in the average processing room. Where the amount of developer solution removed and replenisher added is carefully controlled, the number of replenishments can be extended. However, as more replenisher is added in excess of about 3 times, a slight decline in contrast will be noted even though similar densities are maintained in the radiographs.

Figure 3.9. Test for developer activity.



Testing developer activity

The easiest way of making a test for developer activity is to process at frequent intervals film strips exposed in a standard manner and to compare the densities obtained with an identical strip processed in fresh solution.

The standard strip cut from a sheet of film which has been exposed to direct x-rays through a test object, such as an aluminum step tablet, when given the proper exposure should produce a series of densities which will cover the density range used in practice.

It is essential that all strips used in testing a batch of developer receive identical exposure. For this reason films are kept in their paper protective folders during exposure and subsequent storage. Screens are not normally used for this particular test.

When processed, test strips should be given the same development time and agitation that will be used in practice.

When a new batch of developer is placed in use, one or more strips are processed and preserved as a standard of comparison throughout the useful life of the developer; thereafter a strip should be processed each day. If the densities of the test strip are less than those of the strip processed in the fresh solution, the rate of addition of replenisher should be increased, or, if the exhaustion method is used, development time should be increased. If the densities of the test strip are too high, the rate of addition of replenisher or the development time should be decreased.

The comparative strip will also enable one to detect the presence or absence of chemical fog.

WATER RINSE BATH (MANUAL PROCESSING)

After development, the x-ray film should be rinsed for 30 seconds in circulating fresh water to remove not only the soluble chemicals of the developer retained on the surface of the film but also those in the pores of the emulsion. The rinse is necessary since, when insufficiently rinsed films are placed directly in the fixing bath, the chemical balance of the fixer is eventually disturbed and its useful life shortened. Omission of the rinse bath will also produce stains on the radiograph. On removal from the rinse bath, films should be drained and then placed in the fixing solution.

ACID RINSE BATH (MANUAL PROCESSING)

The use of an acid rinse bath serves to prolong the life of the fixer solution. An acid rinse bath eliminates the need for running water as required by a water rinse bath. The most efficient rinse or stop bath, according to Fuchs, is one consisting of a dilute solution of acetic acid in water made according to the following procedure: add 2½ quarts of 28-per-cent acetic acid to 1 gallon of water; stir thoroughly; add sufficient water to make 5 gallons of solution.

THE FIXER (MANUAL PROCESSING)

The functions of the fixer or hypo solution are: (1) to dissolve the undeveloped silver halide particles in the film emulsion and to remove these dissolved silver salts so that subsequent washing will leave the radiographic film inactive to any further action of x-rays or light; (2) to harden the gelatin coating so that the film may be dried after washing. The interval between the placing of the film in the fixer solution and the complete disappearance of its initial diffuse opaqueness is known as the *clearing time.* It is during this time that the fixer solution converts the silver salts to a soluble condition and removes most of them from the emulsion. The fixing time is the total period during which films must remain in the fixer solution to remove the undeveloped silver salts and to harden the gelatin.

Table 3.3 X-RAY FIXER

Chemical	*General function*	*Specific function*
Sodium thiosulfate (hypo)	Fixing agent	Dissolves unexposed silver bromide crystals, does not affect reduced metallic silver of image
Sodium sulfite	Preservative	Maintains equilibrium of chemicals in solution
Potassium alum	Hardening agent	Shrinks and hardens emulsion
Acetic acid	Acidifier	Provides acid medium and neutralizes developer carried over in film

Test for clearing time

In determining the clearing time, it is important that *unexposed* x-ray film be used. The film is first developed and rinsed and then placed in the fixer solution, where the disappearance of its initial milkiness is observed. It is desirable to leave films in the fixer solution for at least twice the clearing time.

Temperature and agitation

It is important that the developer, intermediate rinse water, and fixer be maintained at a constant temperature since the activity of both developer and fixer is increased if the temperatures of the solutions become elevated. The fixing time for x-ray films is shortened when films are agitated. By agitation a greater volume of the fixer solution is brought in contact with the films and rinse water is more rapidly removed from the film surface.

Replenisher for fixer solution

During use a fixer solution becomes diluted by developer and rinse water carried over into it by the films. As a result, the rate of fixation decreases, and the hardening action is impaired. The accumulation of soluble silver salt in the solution gradually impairs the fixer's ability to dissolve silver in the emulsion. The dilution can be partially prevented by thoroughly rinsing and draining the films before their emergence in the fixer, and the fixer solution can be restored by replenishment.

Silver recovery and prolongation of the hypo bath

The main factor in exhaustion of the hypo or fixing bath is the accumulation of silver. Since the silver is not readily recoverable from the solution, the common practice is to use the fixing bath until it becomes "slow" and then to discard it or sell it for a fee to a solution service company.

Interest in silver recovery for the small and large department has been increasing in the last few years. There are several processes, all of which use, by necessity, low-current density and therefore have a slow silver-recovery rate. If high-current density is used in this type of unit, silver sulfide will be formed. Some of these units have the advantage of being so constructed that they will fit in the fixing tank and allow continual operation while the tank is actually being used. In a busy x-ray department the rate at which silver is dissolved into the fixing bath exceeds by far the ability of these units to recover the silver and breakdown of the solutions is still faster than it should be.

Employment of a silver-recovery unit reduces the hazard of staining clothing with spots of fixer solution and extends the life of the fixer.

WASHING PROCESS

The washing time for x-ray films is important since washing removes residual processing chemicals and silver salts from the radiographs. Normally, x-ray films should be washed in running water in such a manner that the entire film will receive frequent changes. The bar of the hanger and the top clip should always be completely covered by the wash water.

The time required for adequate washing depends principally upon the type of x-ray film to be washed, the rate at which the water flows through the tank, and the temperature of the water. Depending upon the water flow, the washing time ranges from 5 minutes to 40 minutes.

MANUAL PROCESSING – 1 TO 10 MINUTES, 60° TO 75°

X-ray film has three characteristics – *contrast, speed* or *density,* and *fog.* On the graph shown in Figure 3.10 we can plot developing time in minutes from 1 minute to 8 minutes, and we can see at a glance whether the speed is *increasing* or *decreasing*; the same is true of *contrast* and *fog.*

Figure 3.11 is a cross section of film emulsion given identical exposures but developed for 3 and 5 minutes. The section developed for 5 minutes has greater concentration of black metallic silver. This *increase* in silver is what gives us the increased density or speed as shown on the radiograph.

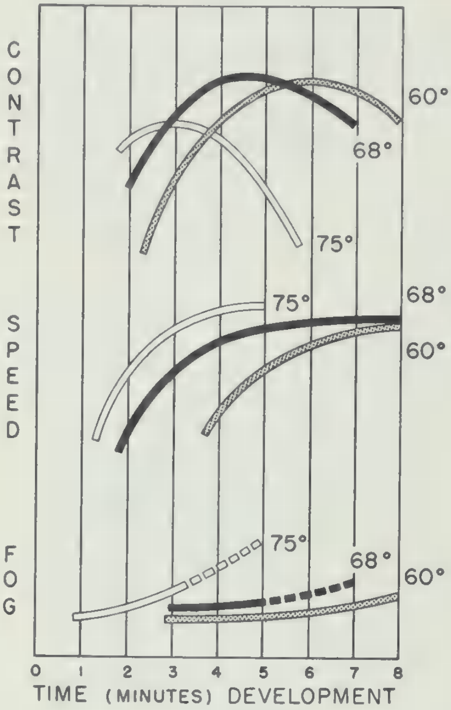
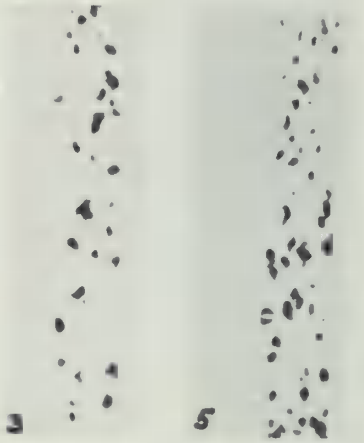


Figure 3.10. The effects of variations in time and temperature on contrast, speed, and fog.

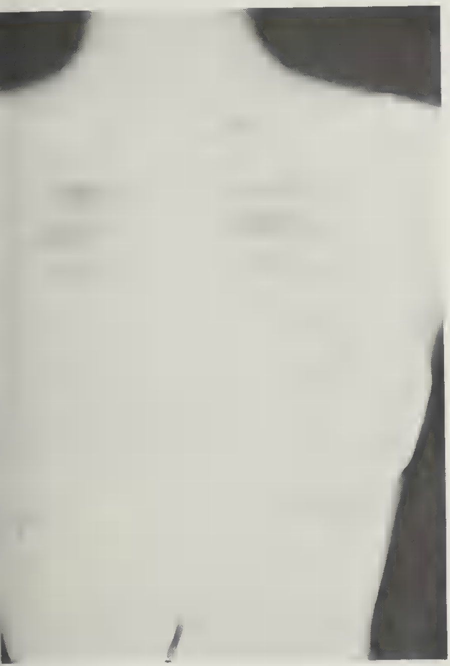
Figure 3.11. Cross sections of film emulsions that have been given identical exposures. At left, a development time of 3 minutes; at right, of 5. Note the increasing density.



Let us study the speed curve of Figure 3.10 and the radiographs of Figures 3.12 and 3.13. Figure 3.12 was developed for 2½ minutes at 68°, Figure 3.13 for 5 minutes at 68°. Notice the increased density or speed of the film, given the recommended processing time of 5 minutes. There is a little more speed beyond 5-minute developing, as is shown in Figure 3.14, processed for 6½ minutes at 68°.

Now look at the second characteristic on the curve – contrast. Review Figure 3.12, the radiograph developed for 2½ minutes at 68°, and Figure 3.13, developed for 5 minutes at 68°. At 6½ minutes, notice how the contrast has gone down on the black curve. Also note the radiograph in Figure 3.14. Why is it that contrast has fallen off at 6½ minutes? The reason is *fog – chemical fog.*

Observe the fog curve. First note $2^1/_2$ minutes on the curve and radiograph A. Now look at radiograph B developed for 5 minutes at 68° and note the fog curve. The fog has increased a little, but is insignificant. At $6^1/_2$ minutes on the curve, fog has increased to such a point that it has resulted in the *loss of contrast* in the radiograph. Compare Figure 3.14, developed for $6^1/_2$ minutes at 68°, with Figure 3.13.



e 3.12. Radiograph 1, developed for $2^1/_2$ minutes

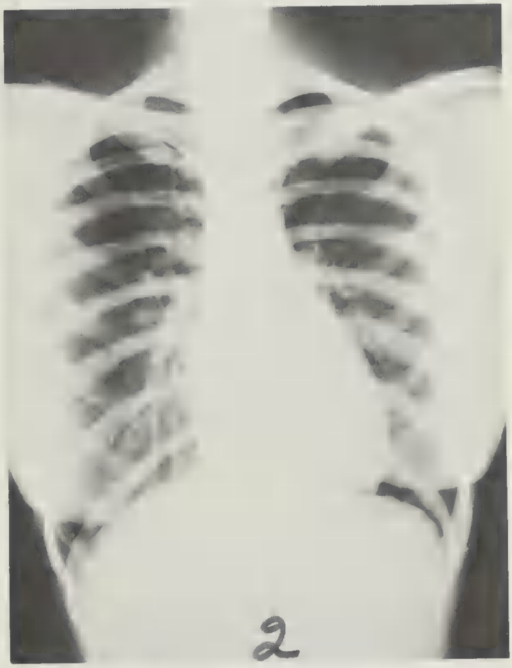


Figure 3.13. Radiograph 2, exposed like 1 but developed for 5 minutes at 68°.

In studying these curves and these three radiographs, one can readily see why 5 minutes at 68° was chosen as the recommended processing time for screen type film. It gives the highest contrast with satisfactory speed at a *low* fog level. We have less fog at $2^1/_2$ minutes, but we also have less contrast.

Study Figures 3.15, 3.16, and 3.17 and the white curve in Figure 3.10. At $3^1/_2$ minutes on the white curve, 75°, the speed is greater than at 5 minutes at 68° on the black curve. Notice what is happening on the contrast curve at 75°. At $3^1/_2$ minutes the contrast is about equal to that at 68°, at 4 minutes the contrast falls off, and at 5 minutes it drops way down. Compare Figures 3.15, 3.16, and 3.17 with Figure 3.13, developed for 5 minutes at 68°. Why is it that contrast falls off so badly at 75°? The reason is fog. Notice the white fog curve.

Look at the radiographs in Figures 3.18 and 3.19. Figure 3.18, processed for 5 minutes at 60° (gray curve), provides contrast almost equal to the topmost point on the 68° curve. However, the speed at that processing time

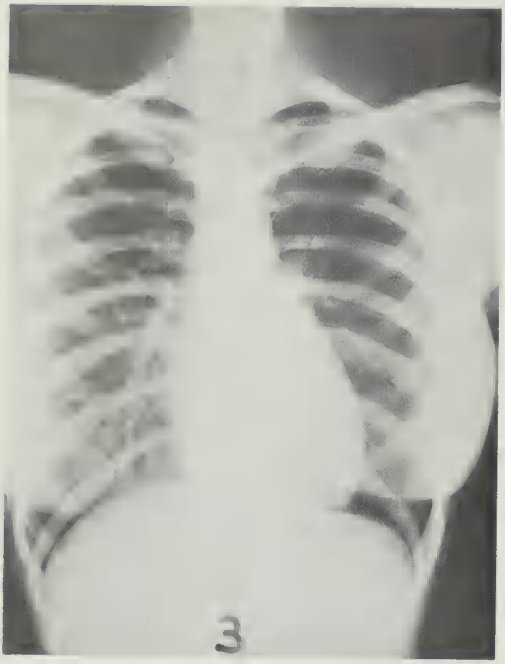


Figure 3.14. Radiograph 3, like 1 and 2, but developed for 6½ minutes at 68°.

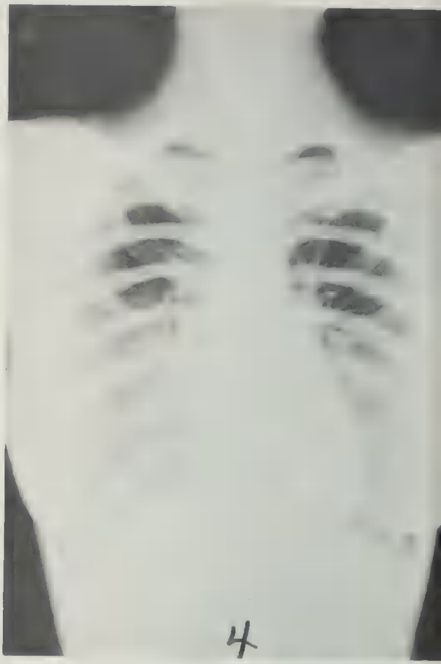


Figure 3.15. Development at a higher temperat
3½ minutes at 75°.

Figure 3.16. Development for 4 minutes at 75°.

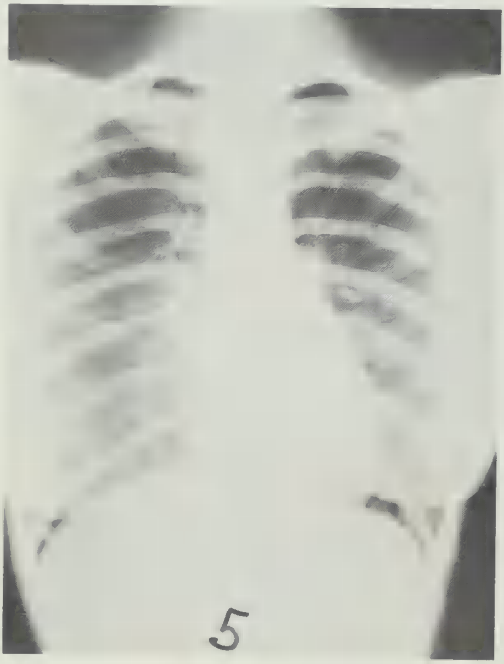
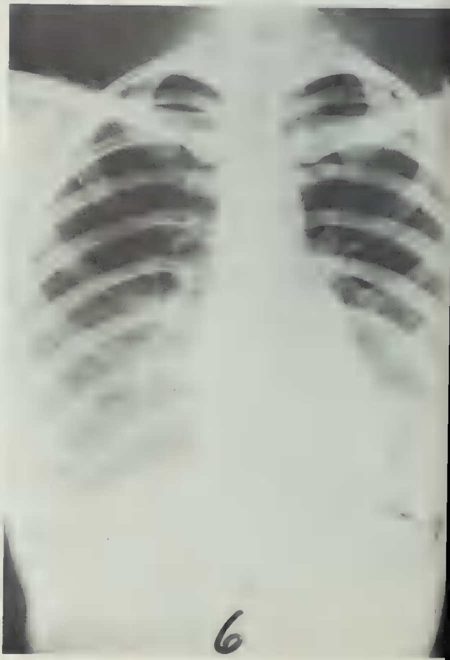


Figure 3.17 Development for 5 minutes at 75°.



re 3.18. Development at a lower temperature—
nutes at 60°.

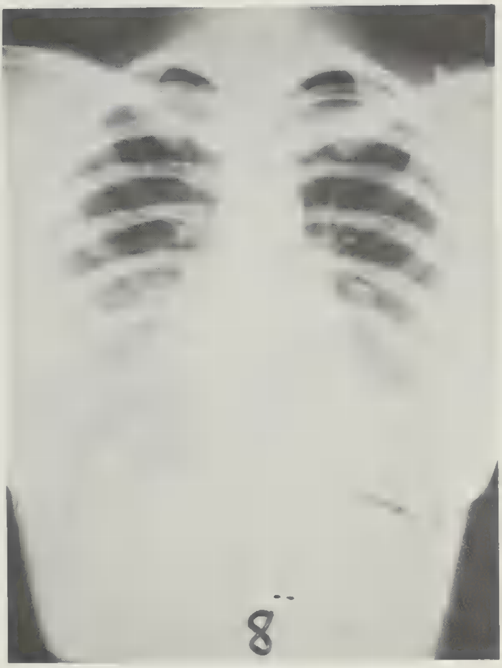


Figure 3.19. Development for 10 minutes at 60°

re 3.20. Development for 4 minutes at 68°

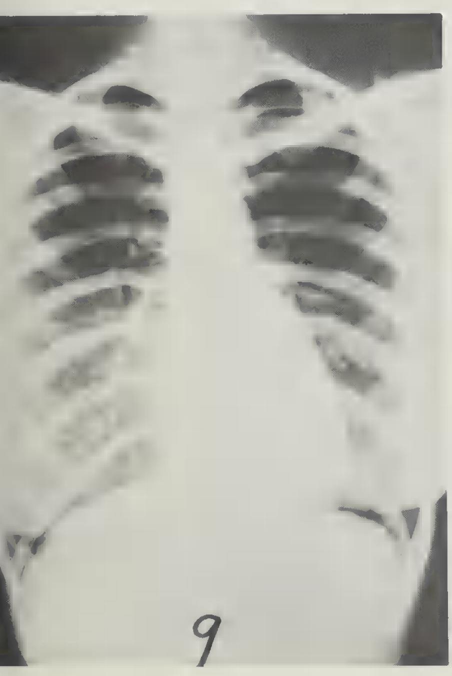
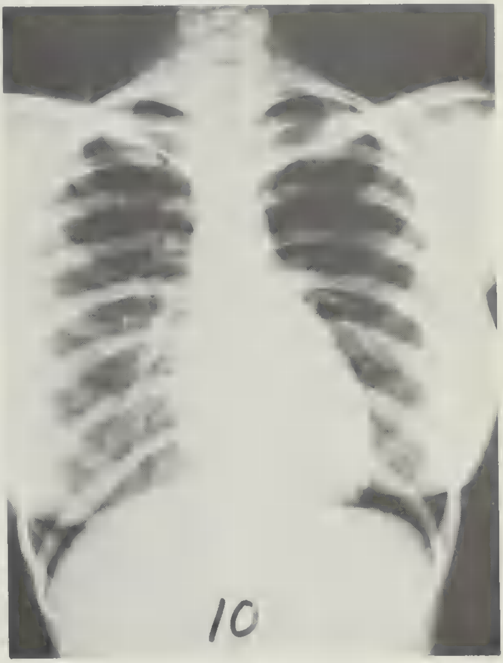


Figure 3.21. Development for 5 minutes at 68°.



is quite low. This great sacrifice in speed therefore makes this procedure impracticable. As we increase the developing time to 10 minutes (Figure 3.19), the speed becomes better but the contrast falls off.

Compare Figures 3.20, 3.21, and 3.22. Figure 3.20 was processed for 4 minutes at 68°; Figure 3.21, for 5 minutes at 68°; Figure 3.22, for 6 minutes at 68°. Using 5-minute developing at 68°, we are permitted an error of 1 minute, either above or below 5 minutes. This is demonstrated on the speed curve by showing small changes and their effects, also by the contrast and fog curve. If we should adopt a 3- or 3½-minute developing time and make an error of 1 minute on either side, you can see what terrific variations we would get in density and what huge differences in contrast. The fog level is about the same.

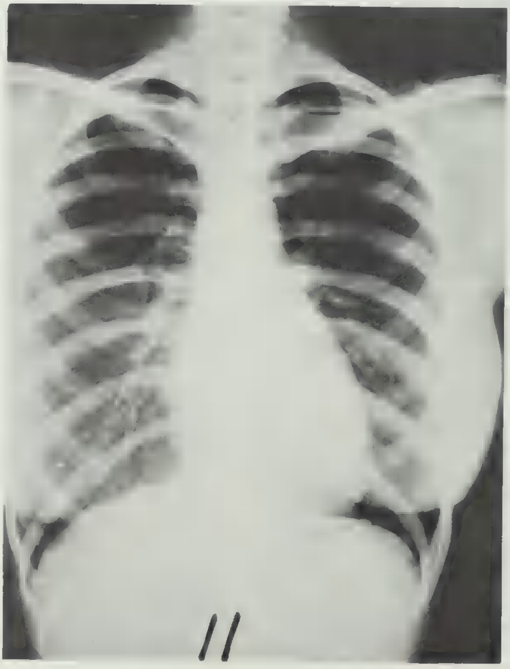
One of the most important reasons for developing for 5 minutes at 68° is the reduction in exposure to the patient (30 to 35 per cent less Ma.S.) over the 3 or 3½ minute developing.

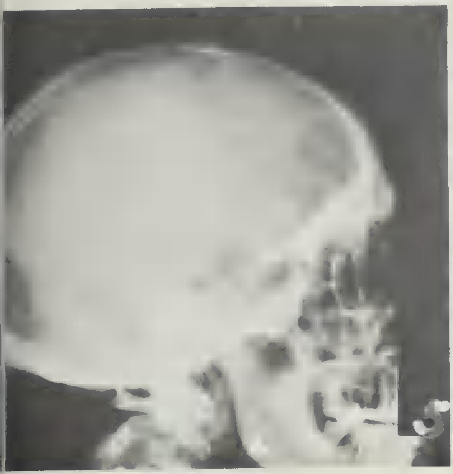
It is almost impossible to overdevelop a radiograph if the film has been properly exposed. Figures 3.23 and 3.24 were made of the lateral skull and developed for 5 minutes at 68° and 10 minutes at 68°, respectively. The only difference is the level of chemical fog in the radiograph developed for 10 minutes.

AUTOMATIC PROCESSING

In automatic processing, film is transported at *higher* temperatures

Figure 3.22. Development for 6 minutes at 68°.





e 3.23. Development for 5 minutes at 68°

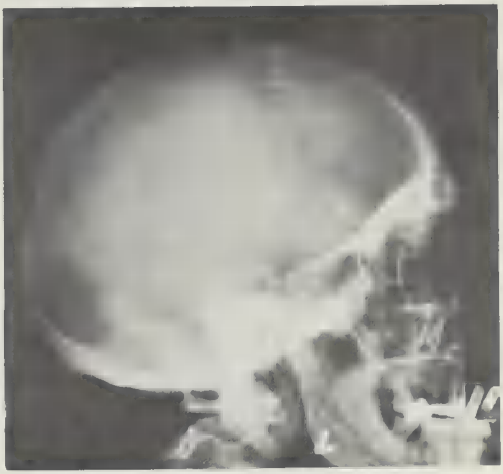
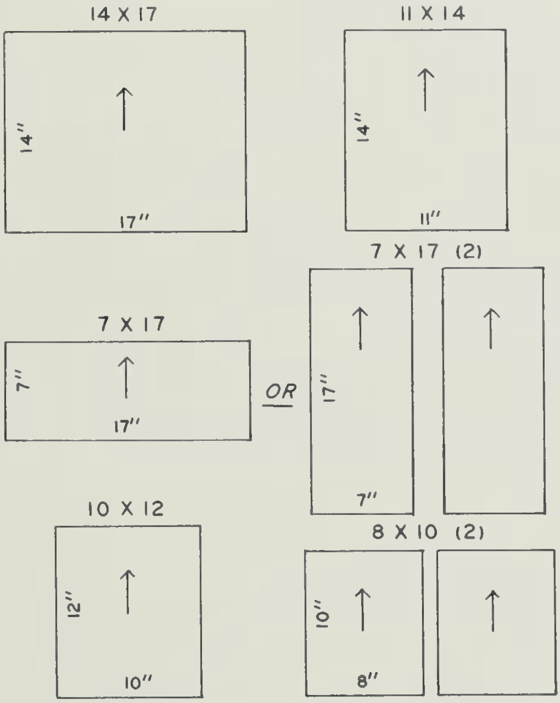


Figure 3.24. Development for 10 minutes at 68°

Figure 3.25. Film-feeding patterns with automatic processing.



through developing, fixing, and washing stages prior to hot air drying. The wet-to-dry cycle is primarily made possible by drastically reducing the time required for washing and drying. In order to achieve this, the film must be conditioned chemically in the wet section. To minimize film swelling and to prevent the emulsion from adhering to the rollers, a hardening agent is incorporated in the developer.

The key to the best in film quality in automatic processing is *uniform replenishment*. Careless or improper film feeding results in a wasteful increase in the amount of solution used.

If a 14 x 17-inch film is fed the 17-inch way instead of the 14-inch way, the replenisher microswitch is activated by 17 inches of film travel, instead of 14 inches. This results in overreplenishment by a factor of 22 per cent. It is of utmost importance that films be fed the proper way in order to avoid overreplenishment, which results in excessive density.

The replenishment rates for medical screen-type film will vary depending on the *type* and *brand* of film and the *exposure* employed.

Rapid processing chemicals (90 seconds)

The chemicals in rapid processing are somewhat different than the chemicals used for manual processing. The chemicals of the Hunt Company are composed of the following:

A. *Developing Agents*

Phenidone—Quickly builds up gray tones in the image. Phenidone is more resistant to deterioration than metol, and more concentrated than metol.

B. *Special Ingredients*

Cycon—Replaces various inorganic salts in automatic processing formulas. Cycon is much more soluble and thus affords greater concentration than sodium sulfite.

C. *Hardener*

Glutaraldehyde—Controls emulsion swelling to allow better transportation of films through the processor.

Chemicals and their function in a fixing bath

A. *Fixing Agent*

Ammonium thiosulfate
Sodium thiosulfate

The fixing agent clears away the unexposed silver bromide crystals. Ammonium thiosulfate is vastly more efficient than sodium thiosulfate and is used in all liquid fixers for automatic processing.

B. *Acidifier*

Acetic acid
Sulfuric acid

The acidifier stops development by neutralizing the developer and provides required acidity.

C. *Hardener*

Aluminum sulfate
Aluminum chloride

D. *Preservative*
Sodium sulfite
The preservative maintains the chemical balance of the fixer chemicals.

E. *Solvent*
Water
The solvent is the liquid for dissolving chemicals.

SOME QUESTIONS ON 90-SECOND PROCESSING

Is there any reason, apart from the value of acid in neutralizing the developer, why a fixer should be acid in pH?

Yes. The aluminum sulfate and chloride hardeners are effective only in an acid solution. Wetness or tackiness in film coming out of a processor may be caused by a fixer with a pH that is not acid enough. But there are many other reasons why wet films are produced—for example, inadequate replenishment of the fixer, and a dryer that is set too low.

What is clearing time?

Clearing time is the length of time needed to completely remove the undeveloped silver bromide from the film. Hunt Graph-O-Mat 90 Fixer will effectively clear 90-second film in an automatic processor in about 6 or 7 seconds.

Why do 90-second films fix so rapidly?

The 90-second films have a lower gelatin content than other films. The lower the ratio of gelatin to silver bromide in a film, the easier it is for the developing agents to get into the emulsion and convert the exposed silver crystal to black metallic silver. In other words, a man can run through a doorway faster alone than when three men hit it together. The same is true in washing. The less gelatin, the less thiosulfate it holds. Then the wash water has an easier job to do, since it can get into the emulsion easier because of the lower gelatin content and since there is less thiosulfate (hypo) to remove. Another factor in speed is the fast flow of water (2 to 4 gallons per minute) in an automatic processor. This flow prevents water, laden with thiosulfate, from remaining in proximity to the films. The higher temperature of wash water in 90-second processing makes washing more efficient, and the agitation caused by the rollers and by incoming water hastens the action.

Suppose one shut down the processor with a film in the fixer tank. What would happen overnight?

The fixer would bleach out the developed black silver image. This, of course, rarely occurs, but in manual operation there have been cases of the technician pulling a film out of a fixer tank after a night of immersion and finding it blank.

What causes the blotchiness on films which is made visible by reflected light?

This effect, which is often described as random shiny and dull areas on the film, is caused by *variation in the rate of drying.* The drive rollers, while in contact with the film, momentarily prevent the forced air that is circulating through the chamber from reaching the contact areas. This effect can be reduced by lowering the dryer temperature to the lowest safe setting. Lower the temperature until films show some dampness; then increase the temperature until this condition disappears.

What effect can be expected from temperature variations in the developer?
Higher temperature will cause an increase in speed, density, and fog. Temperatures lower than normal will have the opposite effect. Higher temperatures in the developer will cause more emulsion swell and an increase in the carry-over into the fixer. At times, even properly replenished fixer will be affected, and the result will be wet films.

What effect can be expected when the developer-recirculating system is not functioning?
Light films and generally lower density.

What causes grayed-out films of insufficient contrast and density?
Assuming that the x-ray equipment is functioning properly, the main reason is usually exhausted developer caused by underreplenishment, or improper mixing (usually overdilution). Replenishment rates may be set too low or there is probably a mechanical problem, e.g.:

(*a*) The microswitch is not operable;
(*b*) The pump is not operable;
(*c*) Air has got into replenishment lines;
(*d*) There is a kink or blockage of the replenishment lines.

One clue to underreplenishment is a gelatin coating on the downpath rollers in the developer tank. This coating is sometimes green to grayish in color and indicates lack of hardening.

Ninety-second processing allows increased utilization of examination rooms and equipment; and also the handling of more patients with no expansion of facilities or staff. It means significant speeding up of fluoroscopic and other serial examinations that require processed films during the course of the examination.

The patient benefits by the greater efficiency of the radiologic team in terms of better care. Nearly immediate delivery of processed films means greater patient comfort through shortened serial examinations, elimination of patient callbacks. The radiologist can often start treatment sooner, and anesthesia time doing special procedures can be significantly reduced.

The technologist becomes more efficient working with the 90-second processing system. Immediate film access reduces film loss or misplacement. Quality improves because technique can be checked before the patient leaves the room. Finished radiographs can be correlated with the technique used.

Table 3.4 AUTOMATIC PROCESSING TROUBLES AND REMEDIES

Trouble	*Cause*	*Remedy*
Incorrect film density	Incorrect developer starting mix	Replace with correct solution.
	Developer reaching exhaustion	Replace developer with a starting mix and check replenishment.

Table 3.4, continued

Trouble	*Cause*	*Remedy*
Incorrect film density, continued	Over or underreplenishment due to:	
	a. Valve shut off or line clogged	a. Open valve or clean line.
	b. Microswitch not properly adjusted or not functioning properly	b. Check and adjust.
	c. Flow not correct	c. Adjust flowmeter knob.
	d. Flowmeter inaccurate	d. Replace tube and ball.
	e. Air in the lines	e. Bleed air out.
	f. Incorrect film feeding methods	f. See film feeding diagrams.
	g. Leak in system	g. Stop leak.
	h. Replenisher pump failure	h. Replace pump.
	Developer contaminated with fixer (fixer rack used in developer tank by mistake)	Replace developer with starting mix. Be sure fixer rack is in fixer tank. Keep splash guard over developer tanks when removing or replacing fixer rack. Add chemicals through replenisher pump housings.
	Developer temperature too low	Check heaters. Adjust thermostat.
	Inadequate wash-water flow	a. Be sure the stop valves in the water-mixing valves are completely open. b. Be sure all valves in the supply lines are open. c. Check the supply pressure. d. Clean the strainer screens. e. Check that there is not an accumulation of lime deposits within the mixing valve or in the strainers and check valves.
Increase in film density	Developer temperature too high	Adjust thermostat.
	Developer replenishment rate too high	Feed small films in pairs and larger films with long dimension parallel to feed rollers. Check that replenishment rate is correct on flowmeter, then measure overflow from developer tanks to verify this rate.
	Concentration of developer too high	If replenishment rate is correct, remix developer replenisher to proper concentration.
Films stick in dryer	Solution temperatures too high	Adjust thermostat.

Table 3.4, continued

Trouble	*Cause*	*Remedy*
Films stick in dryer, continued	Incorrect developer starter mix (hardener not added)	Remix solution.
	Developer dilution or under-replenishment	Replace developer with starting mix. Check replenishment flow. If not controllable with flowmeter, clear possible restriction or air lock in lines.
	Fixer exhaustion or under-replenishment	Replace fixer. Check replenishment flow. If not controllable by flowmeter, clear possible restriction or air lock in lines.
	Solutions improperly mixed or contaminated	Replace with correctly mixed solutions.
	Foam in solution tanks	Check for air leaking into replenisher lines, recirculating pumps, etc., or clogged drain tube or fitting.
	Recirculation rate of solutions low	Check pumps. Check for clogged or air-locked lines.
	Improper washing	If flow is less than 4 gpm (15 liters/min.): a. See "Incorrect Film Density" above. b. Clear possible restriction in solenoid valves. c. If water flow is completely shut off: 1) Be sure the stop valves in the water mixing valve are open. 2) Be sure all valves in the supply line are open. 3) Check for failure of cold water supply pressure. d. If water temperature varies: 1) Check for lime deposits around the piston of the water mixing valve, causing it to bind in the piston cylinder. 2) Test the thermostatic motor. e. If water flow is untempered hot or cold water, replace the thermostatic motor in the water mixing valve.
Drying streaks on film	Dirty air tubes	Clean.

Table 3.4, continued

Trouble	*Cause*	*Remedy*
Drying streaks on film, continued	Air tubes out of position	Readjust.
Dirty film	Dirty water	Install filter in supply lines.
Scratched film	Improperly seated rollers	Realign and seat properly.
Pi line on films	Fresh chemicals	Lines will disappear after short run.
	Developer contaminated with fixer	Replace developer with starting mix.
Films not drying	Dryer motor running backwards (at installation)	Interchange 2 or 3 power wires.
	Clogged air filter	Replace if necessary.
	Dryer temperature too low	Check for temperature of about 120° F. (49° C.). Check thermostat setting.
	Heater burned out	Replace.
	No exhaust air flow	Repair the exhaust blower or clear clogged vent pipe.
	Chemical imbalance	Check replenishment. Replace fixer and/or developer if suspect.
Fogged film	Light leaking into darkroom	Caulk openings.
	Cover on wet section of processor not fastened properly	Refasten.
	Developer contaminated with fixer	Replace developer with starting mix.
	Chemical imbalance	Replace chemicals.
Other film processing problems	Streaking	Weak developer.
	Mottling	Excessive developer concentration.
	Yellow smudges	Fixer exhausted.
	Lack of clearing	Excessive fixer concentration.
Solids separate out of developer during mixing	Mixing at incorrect temperature	All liquids should be 100–120° F. (38–49° C.) when mixing.
	Pouring additive in too rapidly	Follow mixture exactly.

Table 3.4, continued

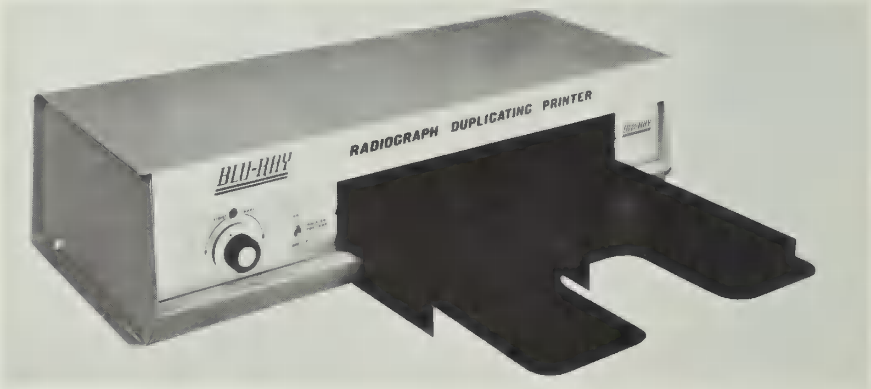
Trouble	*Cause*	*Remedy*
Solids separate out of developer during mixing, continued	Excessive hardener	Use with caution.
Water flows when mixing valve is shut off	Faulty shut-off disc	Replace the shut-off disc.
	Faulty piston cylinder	Replace the piston cylinder.
Maximum water temperature specified is not attainable	Hot water supply to mixing valve not hot enough	Be sure temperature of hot water supply to mixing valve is at least 30° F. (18° C.) above the temperature setting.
Leak occurs around temperature adjustment handle of mixing valve	Packing gland nut not tight	Tighten.
	Faulty packing	Replace packing.

COPIES OF RADIOGRAPHS

Excellent copies of radiographs can be made by employing the Blu-Ray radiograph duplicating machine. The machine is compact and will fit in the darkroom without interfering with loading or unloading cassettes.

To make duplicate radiographs, one need only feed the radiographic duplicating film, which is in contact with the original radiograph, into the Blu-Ray printer. The film is automatically returned in six seconds and is ready for the processor. Figure 3.26 is a photograph of the Blu-Ray machine. Figure 3.27 shows the original radiograph and the duplicate radiograph made with the Blu-Ray apparatus.

Figure 3.26. The Blu-Ray radiograph duplicating machine.



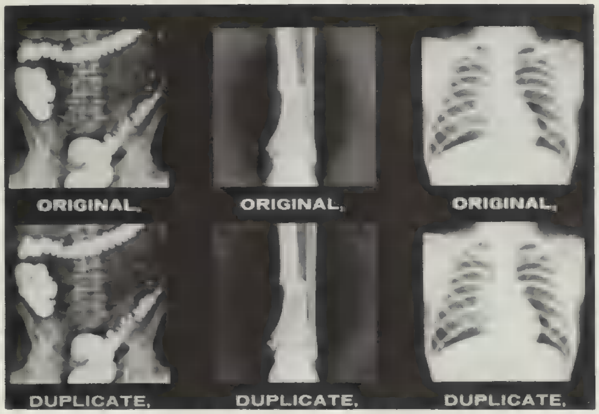


Figure 3.27. Three pairs of radiographs, showing originals and duplicates made by the Blu-Ray machine.

MISCELLANEOUS

Illuminators

Often the technologist overlooks the importance of keeping the illuminators clean. Good, clean illuminators, inside and out, will improve the quality of any radiograph.

One of the best types of illuminators is white flashed opal glass and daylight bulbs. Two bulbs are placed in each 14 x 17 section. The fluorescent bulbs and starter buttons should be checked periodically.

Reduction of overexposed radiographs

Radiographs that have been overexposed may be lightened by treatment with Farmer's Reducer.

Solution A

Potassium ferricyanide	.25 oz. (7.5 c.c.)
Water to make	32 oz. (1 liter)

Solution B

Sodium thiosulfate (hypo)	6.75 oz. (200 c.c.)
Water to make	32 oz. (1 liter)

Treat the radiograph for one to three minutes (or longer) in solution A, then four to five minutes in solution B. Wash the film thoroughly. It is best to use a tray for this procedure.

Clearing film base

Emulsions may be removed by placing the undeveloped film in hypo for 5 minutes and thoroughly washing for 5 minutes.

Removing spots caused by solutions

There are a number of commercial stain removers, but a simple, inexpensive method of removing stains caused by processing solutions from white cotton fabrics is as follows. First, soak the area for a short time in fresh water; this will remove most developer stains. If the spot remains, moisten it with a solution of 1 part tincture of iodine and 1 part water. After several minutes, wet the material with *fresh unused* hypo. Then rinse thoroughly in water. Repeat if necessary. This is not recommended for nylon uniforms.

For nylon uniforms, the stained fabric must be treated with a solution made up as follows:

Sodium hypochlorite 5 per cent	½ oz.
Acetic acid 5 per cent (vinegar)	½ oz.
Water at 100° F.	1 gal.

Developer stains on hands

To remove developer stains from hands and fingernails, prepare the following solutions.

Solution A

Potassium permanganate	¼ oz.
Water	32 oz.

Solution B

Sodium bisulfite	16 oz.
Water	32 oz.

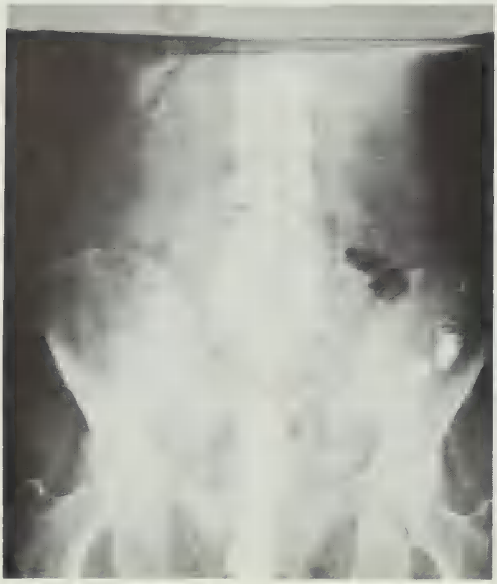


Figure 3.28. The result of a deficiency in both developer and hypo.

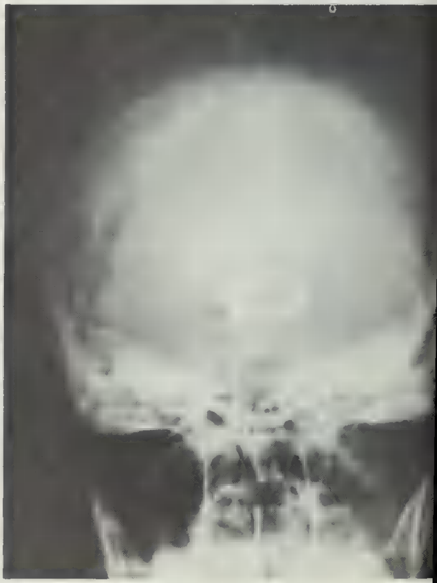


Figure 3.29. An A.P. radiograph of the skull. the rubber band—around a ponytail.

Moisten the stain with solution A. Remove the stain produced by solution A with solution B. Wash in the usual manner with soap and water, and then use hand or cold cream.

Opalescence

Sometimes a film viewed immediately after fixation in a fresh solution has a slightly milky appearance or opalescence. This condition, however, is transient, disappearing when the film is washed and dried.

Tank capacity

The actual volume of a processing tank can be computed by the following formula:

$$\frac{\text{width x length x depth}}{231} = \text{number of gallons.}$$

One gallon of solution displaces 231 cubic inches.

Table 3.5 DARKROOM RULES

Rules	*Reasons*	*What to do*
General	*General*	*General*
1. Don't use a darkroom without adequate lead protection.	Lead protects the film from fogging and the technicians from x-ray exposures.	Insist upon adequate lead protection; usually, 1.5 mm. of lead.
2. Don't permit the darkroom to become too hot. Keep at about 75° F.	A hot room makes the regulation of solution and temperatures difficult.	Use electric fans and outside ventilation if possible.
3. Don't guess at processing times.	Most individuals cannot estimate time accurately enough for darkroom requirements.	Always use darkroom timer or clock.
4. Don't store large quantities of films.	Films deteriorate with age.	Keep a small surplus; renew your supply frequently.
5. Don't keep boxes of films lying flat.	Static charges of electricity may collect from pressure.	Stand film boxes on end
Cassettes and screens	*Cassettes and screens*	*Cassettes and screens*
6. Don't permit screens to become dirty.	Dirt reduces screen sensitivity, resulting in spotted films.	Wash screens monthly—use pure grain alcohol and lint-free cloth.
7. Don't load, unload, or leave cassettes near processing tanks.	Drops of liquid may be splashed on the screens, reducing their sensitivity.	Keep loading bench far away from solutions.
8. Don't leave cassettes open.	Exposes screens to damage by dirt, liquids, and other objects.	Keep cassettes closed when not in use.
9. Don't rub or scratch screen surfaces.	Decreases screen life by destroying protective coat.	Brush screen surface lightly—use soft materials, such as camel's-hair brush.
10. Don't touch screen surfaces with your fingers.	The oil in fingerprints reduces screen sensitivity.	When exchanging screens, touch only the edges.

Table 3.5, continued

Dry films	*Dry films*	*Dry films*
11. Don't bend, crease, press, or buckle films.	Black, half-moon marks may occur.	Handle films carefully to keep surfaces flat and smooth.
12. Don't scratch films with fingernails or other hard objects.	Scratches appear as light or dark streaks on films.	Use fingertips and not nails when handling films.
13. Don't slide or shuffle dry films over flat surface.	Films may become scratched; static electricity may develop.	When films are moved, free them from all supporting surfaces.
14. Don't leave film boxes uncovered.	Films become fogged with irregular markings.	Keep film boxes closed and in dark cabinet when not in use.
15. Don't pile films on top of one another before mounting on the hangers.	Static electricity may be developed	When film is removed from the cassette, place it on a hanger immediately.
Chemicals and solutions	*Chemicals and solutions*	*Chemicals and solutions*
16. Don't use same paddle to stir developer and hypo.	Developer may become contaminated with hypo.	Have one paddle for developer; another for hypo.
17. Don't mix developer in vessels other than glass, stainless steel, enamel, or earthenware.	Other materials contaminate the solutions and destroy their action.	Use glass, stainless steel, enamel, or earthenware vessels for mixing solutions.
18. Don't use scouring powder to cleanse the tanks.	Scouring powder is difficult to remove. May "spot" films.	Use stiff brush and water to cleanse tanks.
19. Don't leave solutions uncovered when not in use.	They may become contaminated with dirt. Loss of water by evaporation.	Keep processing tanks covered with semi-tight lid when not in use.
20. Don't use solutions at beginning of the day's work without stirring them.	Solid chemicals may collect on bottom of the tank. Solutions become stratified.	Develop a habit of stirring solutions when they have not been used for a few hours.
21. Don't fail to agitate films for a few seconds when placed in the solution.	Formation of air bubbles is prevented and new solution is brought to the emulsion surface.	Move films slowly up and down and back and forth without exposing any part to air.
22. Don't remove films from solution too rapidly.	Excess solution is carried away from the tank.	Use 5 seconds in removing the film. Allow 5 seconds for draining.
23. Don't permit developer to drop below the proper level.	Portions of the film surface may be exposed above the developer.	Check level frequently. Add developer to maintain proper level.
24. Don't add water to developer to maintain proper level.	Developer will become diluted and therefore slower in its action on the films.	Keep a bottle of replenisher nearby with which to replenish.
25. Don't ever put a film in the developer after it has been in hypo.	Hypo destroys alkalinity of the developer.	Keep well in mind the relative positions of the developer and the hypo tanks.
26. Don't crowd films in the developing tank.	Films may rub together and become stuck.	Allow at least 1 inch of space between films.
27. Don't transfer films directly from developer to hypo without rinsing in water.	Excess developer on the film surface will be carried to the hypo.	Always rinse films in water or stop bath before putting them into the hypo

Table 3.5, continued

Fixing	*Fixing*	*Fixing*
28. Don't allow hypo to drop below proper level.	Portions of the film may not be "fixed."	Add hypo if necessary. Keep tank covered when not in use to prevent evaporation.
29. Don't add water to hypo to maintain proper level.	Hypo becomes diluted.	Add hypo, not water.
30. Don't attempt to clear films in exhausted hypo.	Films may become brown on aging.	Use new hypo.
Washing	*Washing*	*Washing*
31. Don't guess at washing times.	Incomplete washing may occur, or emulsion may be softened and frilled.	Fifteen minutes in water changing at rate of eight tanks per hour.
32. Don't allow wash water level to become too low.	Tops of hangers may not be cleansed. Films become streaked with hypo.	Keep entire film and hanger below surface of the wash water.
33. Don't use wash water below 50° F.	Washing time is increased at the low temperatures.	Maintain wash water temperature above 50° F.
34. Don't use wash water above 80° F.	Frilling of film emulsion may occur.	Maintain wash water temperature below 90. F.
Handling wet films	*Handling wet films*	*Handling wet films*
35. Don't lay wet films on flat surfaces.	Emulsion may stick to the surface and be removed from film base.	Make the processing procedure continuous until films are dry.

e 3.30 The result of improper hypo and wash

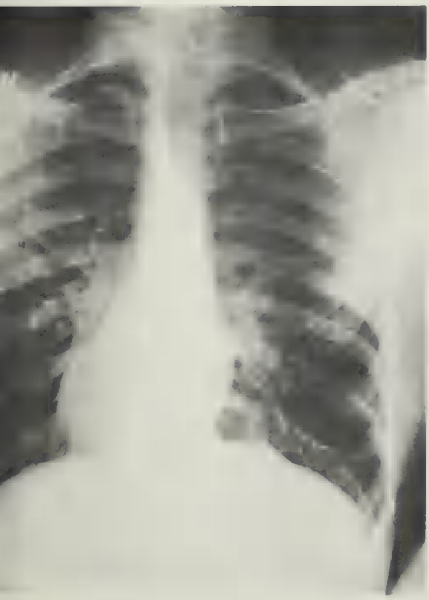


Figure 3.31. A lateral radiograph of the skull: a product of overpenetration and underdevelopment.

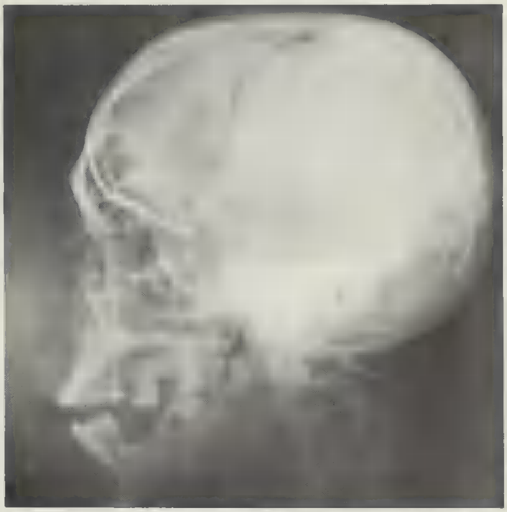


Table 3.5, continued

Drying	*Drying*	*Drying*
36. Don't dry films at too high temperature.	Rapid drying may result in uneven drying, with warping.	Keep dryer temperature between 75° and 90° F.; relative humidity between 15 and 40 percent.
37. Don't crowd films in the dryer.	Films may become stuck together. Inadequate circulation of air.	If possible, leave one-half of the spaces unoccupied.

Table 3.6 COMMON CAUSES FOR UNSATISFACTORY RADIOGRAPHS

Defect in Roentgenogram	*Factors attributable to –*		
	Processing room	*Storage room*	*Radiographic room*
Localized blurring of detail	Warping of the surface of intensifying screens – careless mounting or handling		
Repeated outlines of hairs, dust particles, etc. – decreased radiographic densities	Accumulations of such on the surfaces of the screens – failure in routine cleaning Pitted or torn surfaces of intensifying screen		
Mottled areas of blackness, usually extending centrally from borders	Light leak into film loading bin Light leak through worn edges of cardboard holder or cassette	Careless opening of film carton in lighted room Prolonged storage in flat position with sensitizations of emulsion due to impacts	Careless handling of cardboard holder or cassette with light admission into either
Widespread fogging	Leakage of x-radiation into processing room Sight development Hot chemicals Excessive heat in storage bin	Films stored too close to radiator or hot pipes; excessive heat in storage room X-radiation leakage in the storage room (also possibility of gamma ray exposure from near-by radium)	Minimal x-radiation exposure before or after the roentgenographic procedure Excessive secondary radiation – need for grid, cone, or diaphragm
"Christmas tree"-like" or circular densities with feathery margins	Static discharges (especially incident to rough removal of film from protective black paper) Impacts	Impacts; rough handling	Impacts; rough handling of cardboard holders and cassettes

Table 3.6, continued

Moon-shaped or V-shaped areas of decreased density	Bending of film incident to fingernail pressure or creasing of the film		
Fusiform areas of decreased density	Close contact of buckled portions of two films in developer		
Transfer of image from one film to another	Slight contact of emulsion surfaces of two films in developer		
Streaky densities	Sight development Hot solutions		
Insufficient densities	Old (oxidized) developer Cold developer		Underexposure
Strip of transparent base at one end of film with sharp demarcation or bubble outline	Level of developer too low – not covering entire film		
Grayish yellowish strip at one end of film	Level of hypo too low – not covering entire film		
Yellowish discoloration throughout roentgenogram	Old (oxidized) hypo		
Fusiform area of of grayish yellow or yellow	Close contact of emulsion surfaces because of buckling of films in hypo		
Rough, whitish, or crystalline surface – noted after drying	Inadequate washing of film after hypo		
Crinkled surface	Excessive heating of wet emulsion – likely during processive drying		

Table 3.6, continued

Defect in Roentgenogram	*Factors attributable to—*		
	Processing room	*Storage room*	*Radiographic room*
Bubble or track bucklings	Dropping of water or chemicals onto dried film		
Lack of sharpness in detail	Defective intensifying screens; fast screens with large fluorescent crystals		Movement of patient or of film or of tube during exposure Use of large focal spot of tube Distortion—associated with short focal-film distance in relation to large part-film distance
Excessive density throughout film	Hot developer		Overexposure
Grid markings			Improper action of grid (see under description of grid function)
Grayness—long scale of gradations of density—lack of contrast	Use of cardboard holders instead of cassette with intensifying screens Shortening of development time because of hot developer		High kilovoltage Secondary fog—need for grid cone or diaphragm
Excessive contrast—short scale graduation	Use of fast intensifying screen—rather than medium or slow screens or cardboard holders Prolonged development in cold developer		Low kilovoltage

I. LOW DENSITY

A. *Underexposure*
  1. Wrong exposure factors
    a. Kilovoltage too low
    b. Milliamperage too low
    c. Exposure too short
    d. Too great focus-film distance
  2. Meters out of calibration
  3. Timer out of calibration
  4. Inaccurate setting of meters or timer
  5. Drop in incoming line voltage
    a. Elevators, etc. on same circuit
    b. Insufficient size of power line or transformers
  6. Central ray of x-ray tube not directed on film
    a. Poor orientation of central ray

Table 3.6, continued

-
    -
        -
            - *b.* X-ray tube rotated in tube carriage
    - B. *Underdevelopment*
        - 1. Improper development
            - *a.* Time too short
            - *b.* Temperature too low (hydroquinone inactive below 59° F.)
        - 2. Exhausted developer
            - *a.* Chemical activity used up
            - *b.* Activity destroyed by contamination
        - 3. Diluted developer
            - *a.* Addition of water instead of fresh developer to raise level
            - *b.* Melted ice from cooling attempt
            - *c.* Overflow of water from wash tank
        - 4. Incorrectly mixed developer
            - *a.* Exact capacity of tank unknown
            - *b.* Mixing ingredients in wrong sequence
            - *c.* Omission of ingredient
            - *d.* Unbalanced formula composition
- II. HIGH DENSITY
    - A. *Overexposure*
        - 1. Wrong exposure factors
            - *a.* Too high kilovoltage
            - *b.* Too high milliamperage
            - *c.* Too long exposure
            - *d.* Too short a focus-film distance
        - 2. Meters out of calibration
        - 3. Timer out of calibration
        - 4. Inaccurate setting of meters or timer
        - 5. Surge in incoming line voltage
    - B. *Overdevelopment*
        - 1. Improper development
            - *a.* Time too long
            - *b.* Temperature too high
            - *c.* Combination of both
            - *d.* Inaccurate thermometer
        - 2. Overconcentrated developer
        - 3. Omission of bromide when mixing
    - C. *Fog (see Section V)*
        - 1. Light-struck film
        - 2. Radiation
        - 3. Chemical deterioration
        - 4. Film deterioration
- III. LOW CONTRAST
    - A. *Overpenetration from too high a kilovoltage*
        - 1. Overmeasurement of part to be x-rayed
        - 2. Subnormal opacity of bones or tissues
        - 3. Meters out of calibration
        - 4. Meters inaccurately set
        - 5. Surge in incoming line voltage
        - 6. Undermeasurement of focus-film distance
    - B. *Scattered radiation*
        - 1. Failure to use Bucky diaphragm
        - 2. Failure to use Lysholm grid
        - 3. Failure to use cut-out diaphragm
        - 4. Failure to use suitable cones
    - C. *Central ray of tube not directed on film*
    - D. *Too short an exposure*
        - 1. Timer out of calibration
        - 2. Timer inaccurately set
    - E. *Underdevelopment*
- IV. HIGH CONTRAST
    - A. *Underpenetration from too low a kilovoltage*
        - 1. Undermeasurement of part to be x-rayed
        - 2. Abnormal opacity of bones or tissues
        - 3. Meters out of calibration
        - 4. Meters inaccurately set
        - 5. Drop in incoming line voltage
            - *a.* Elevators, etc. on same line
            - *b.* Insufficient size of power line or transformer
        - 6. Overmeasurement of focus-film distance
    - B. *Too long an exposure*
        - 1. Timer out of calibration
        - 2. Timer inaccurately set
    - C. *Overdevelopment*
- V. FOG
    - A. *Unsafe light*
        - 1. Light leaks into processing room
            - *a.* Leaks through doors, windows, etc.
            - *b.* Poorly designed labyrinth entrance
                - *i.* Bright light at outer entrance
                - *ii.* Reflection from white uniforms of persons passing through
        - 2. Safelights
            - *a.* Bulb too bright

Table 3.6, continued

- *b.* Improper filter
  - *i.* Cracked
  - *ii.* Bleached
  - *iii.* Shrunken
- 3. Turning on light before fixation is complete
- B. *Radiation*
  - 1. Insufficient protection
    - *a.* Film storage bin
    - *b.* Loaded cassette racks
  - 2. Improper isolation
    - *a.* Radium
    - *b.* Irradiated specimens
- C. *Chemical*
  - 1. Overdevelopment
  - 2. Developer contaminated by foreign matter of any kind
- D. *Deterioration of film*
  - 1. Age
  - 2. Storage conditions
    - *a.* Too high temperature
      - *i.* Hot room
      - *ii.* Cool room but near radiator hot pipe
    - *b.* Too high humidity
      - *i.* Damp room
      - *ii.* Moist air
      - *iii.* Ice-box storage
  - 3. Delivery conditions: moisture precipitation when cold box of film is opened in hot humid room
- E. *Excessive pressure on film*
  - 1. During storage
  - 2. During manipulation in dark room

VI. STAINS ON RADIOGRAPHS

- A. *Yellow*
  - 1. Exhausted, oxidized developer
    - *a.* Old developer
    - *b.* Covers left off tanks
    - *c.* Scum on developer surface
      - *i.* Oil from pipe lines
      - *ii.* Impure water used when mixing
      - *iii.* Dust
  - 2. Prolonged development
  - 3. Insufficient rinsing
  - 4. Exhausted fixing bath

VII. DEPOSITS ON RADIOGRAPHS

- A. *Metallic*
  - 1. Oxidizing products from developer
  - 2. Silver salts reacting with hydrogen sulfide in air to form silver sulfide
  - 3. Improper solder used in repair of hangers
- B. *White or crystalline: milky fixer*
  - 1. Acid portion added too fast while mixing
  - 2. Acid portion added when water is too hot
  - 3. Glacial acetic acid mistaken for 28%
  - 4. Developer splashed into fixer
  - 5. Insufficient rinsing

VIII. MARKS ON EMULSION SURFACES

- A. *Insufficient fixing*
  - 1. Weakened fixer
  - 2. Unbalanced formula
  - 3. Exhausted ingredients
  - 4. Low acid content
    - *a.* Deficient when fresh
    - *b.* Diluted from rinse water
    - *c.* Neutralized by developer because of insufficient or no rinsing
- B. *Blisters*
  - 1. Formation of gas bubbles in gelatin
    - *a.* Carbonate of developer reacting with acid of fixer
    - *b.* Unbalanced processing temperatures
      - *i.* Combination of hot fixer and cool developer
      - *ii.* Combination of cool fixer and hot developer
    - *c.* Excessive acidity of fixer solution
    - *d.* No agitation of film when first placed in fixer
- C. *Reticulation*
  - 1. Unbalanced processing temperatures
    - *a.* Developer
    - *b.* Rinse
    - *c.* Fixer
    - *d.* Wash
  - 2. Weakened fixer with little hardening action
- D. *Frilling*
  - 1. Weakened fixer with little hardening action
  - 2. Hot processing solutions
    - *a.* Developer
    - *b.* Rinse
    - *c.* Fixer
    - *d.* Wash
  - 3. Prolonged washing
- E. *Air bells*
  - 1. Air bubbles trapped on film surfaces preventing development

Table 3.6, continued

2. Dropping film into developer without agitation as soon as immersed

F. *Drying marks from uneven drying of gelatin*
1. Excessive drying temperatures
2. Water marks: drops of water striking semidried emulsion surface
    - *a.* Water trapped on hanger frames
    - *b.* Water splashes
    - *c.* Dirty hangers

IX. SLOW DRYING

A. *Insufficient hardening in fixer*
1. Too short a fixing period
2. Weakened fixer from splashing
3. Exhausted fixer
4. Insufficient acidity

B. *Prolonged washing*

C. *Wash water too high in temperature*

D. *Too high humidity of inlet air*

E. *Too low temperature of inlet air*

X. BRITTLENESS OF FINISHED RADIOGRAPHS

A. *Excessive drying temperatures*

B. *Excessive drying time*

C. *Outlet air too dry*

D. *Excessive hardening in fixer*
1. Too long a period
2. Excessive acidity

XI. STREAKS ON RADIOGRAPHS

A. *Raw stock defects*

B. *Insufficient agitation while processing*

C. *Fog*

D. *Chemically active deposits*

E. *Pressure static*

F. *Scratches*

XII. LACK OF DETAIL OR FUZZINESS

A. *Motion (tube, film, patient)*
1. Inadequate immobilization
2. *Too* long an exposure

B. *Poor contact of intensifying screens*

C. *Improper distance relationship*
1. Object-film distance too great
2. Target-film distance too short

D. *Improper focal spot*
1. Too large
2. Damaged (cracked or pitted)

Chapter 4. **CONES, DIAPHRAGMS, COLLIMATORS, FILTERS, GRIDS, AND STEREORADIOGRAPHY**

One of the most important factors in the production of good quality radiographs is the use of *cones, lead diaphragms,* or *collimators.*

CONES

The value of a cone is far greater than most technologists realize. Cones are most important in the control of secondary radiation fog. By limiting the port of entry of the primary beam, less tissue is irradiated and less secondary radiation is emitted to fog the film. The greatest benefit derived from the use of cones is the increase in contrast, and contrast makes *detail* more plainly visible. Radiographic *density* is also affected, since the total density is reduced in proportion to the amount of secondary radiation fog that is eliminated. See Figures 7.16 and 7.17, p. 148, radiography of the gallbladder.

DIAPHRAGMS

If the proper cone is not available, lead diaphragms can be made and an assortment suitable for all purposes kept on hand. Diaphragms made from

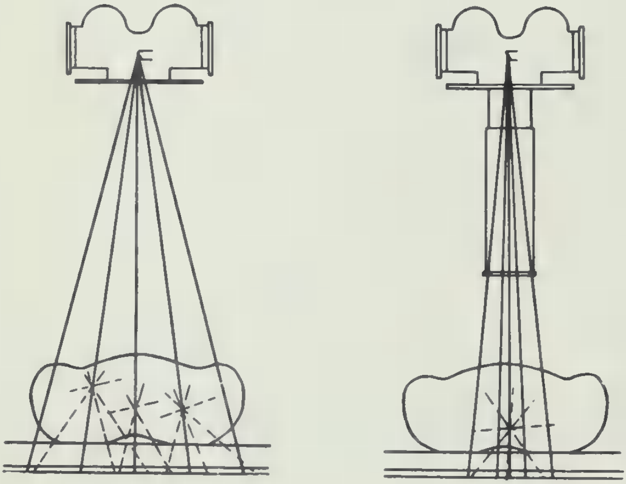
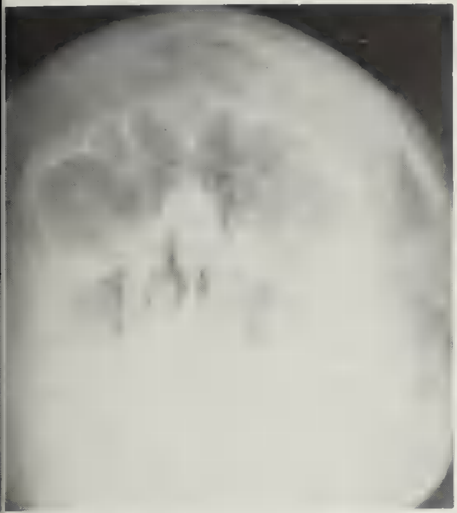


Figure 4.1 Effect of the cone upon densit and contrast. In the diagrams at left, it is t be assumed that only the central portion o the body section shown is of diagnosti interest. In the first diagram, without cone it will be seen that secondary radiation se up in portions of the body outside the are of interest but within the area irradiated b the x-ray tube can reach the film: the resulting secondary-radiation fog will increas density and reduce contrast in the radiograph. The second diagram demonstrate the use of a cone to restrict radiation to th area of interest. Since the area in whic secondary radiation can be set up is reduced, secondary-radiation fog density i the resulting radiograph will be reduce and contrast will be improved.



re 4.2 A radiograph taken without a cone. Note ack of contrast and increased fog density.

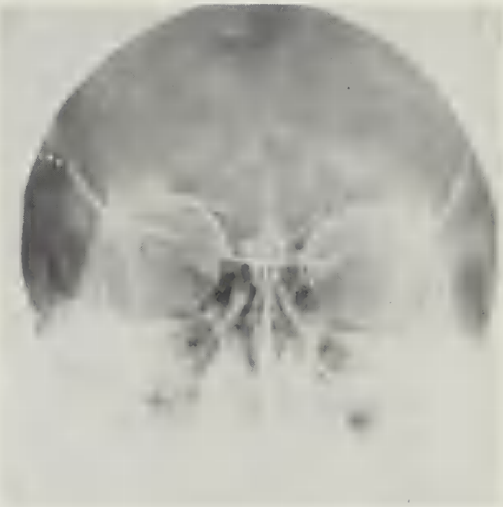


Figure 4.3 The same area as Figure 4.2, taken with a cone.

lead or steel can be cut to fit the filter slot beneath the radiographic tube. Circles of various diameters are then cut in the exact center.

A simple formula for making lead diaphragms is:

$$\frac{\text{anode-diaphragm distance } (A)}{\text{diameter of aperture } (B)} = \frac{\text{anode-film distance } (A^1)}{\text{diameter of projected circle } (B^1)}$$

Example: Suppose that a projected circle 5 inches in diameter is desired when employing a 36-inch focus-film distance and 10-inch anode-diaphragm distance. What must be the diameter of the diaphragm aperture?

$$\frac{10}{x} = \frac{36}{5}$$

$$36x = 50$$

$$x = 1\,{}^{7}/_{18} \text{ inch}$$

In case difficulty is encountered in measuring the distance from the diaphragm to the anode, a diaphragm of any known size aperture may be used and the distance determined by another simple equation:

$$\text{anode-diaphragm distance } (x) = \frac{\text{anode-film distance } (A) \times \text{diaphragm aperture } (B)}{\text{diameter of projected circle } (B^1)}$$

Example: Assume that the anode-film distance (A^1) is 30 inches, the diameter of the diaphragm aperture (B) is 2 inches, and the diameter of the projected circle (B^1) is 6 inches.

$$x = \frac{30 \times 2}{6}$$

$$x = 10 \text{ inches}$$

To make a square diaphragm, simulating the effect of a collimator, we may use this formula: the anode-diaphragm distance is to the anode-film distance as the length or width of the diaphragm opening is to the film area in length or width.

Example: An area of 5 square inches, 1 inch wide and 5 inches long, is desired on an 8 x 10-inch film at a 30-inch anode-film distance and a 6-inch anode-diaphragm distance.

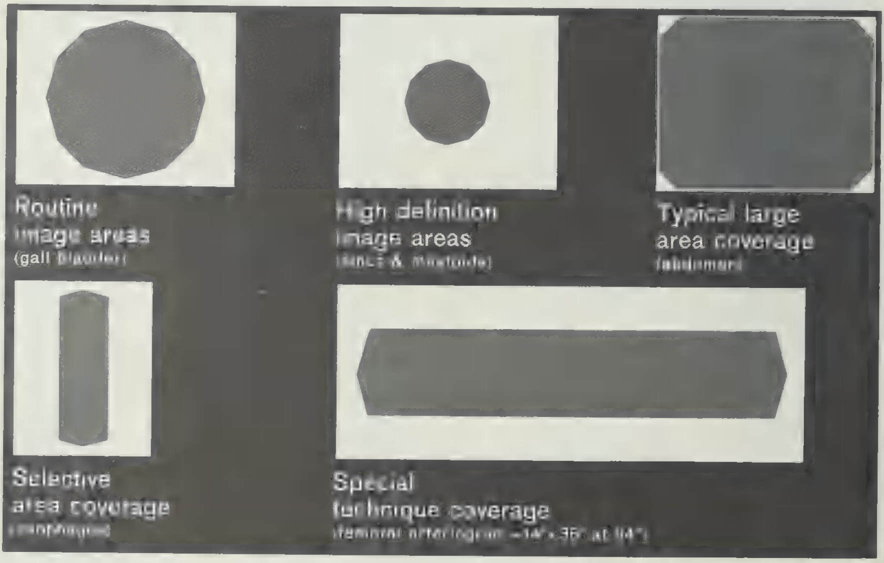
$6 : 30 :: x : 5$
$30x = 30$
$x = 1$ inch = length of diaphragm opening.
$6 : 30 :: x : 1$
$30x = 6$
$x = \frac{1}{5}$ of an inch = width of diaphragm opening.

Therefore, the opening of the lead diaphragm would be 1 inch long and $\frac{1}{5}$ inch wide.

COLLIMATORS

Collimators are devices for shaping the x-ray beam and centering it on a part, usually more flexible and sophisticated than cones and diaphragms. The modern collimator uses light to center the x-ray beam and produces openings by means of several sets of adjustable shutters. Thanks to exact positioning and limiting of the beam area, the patient need not be exposed unnecessarily to x-radiation, and the off-focus radiation that may fog the film is avoided. Available beam shapes vary from near-circular polygons, large and small, to rectangular slots with choice of axis (Figure 4.4). The collimator often allows for the insertion of filters and measuring tapes.

Figure 4.4 Some examples of beam shapes ("geometry") available from the shutter systems of a modern collimator.


Routine image areas
(gall bladder)
High definition image areas
Typical large area coverage
(abdomen)
Selective area coverage
Special technique coverage

FILTERS

The filters normally used in radiography are sheets of aluminum placed between the x-ray tube and the part to be exposed. The thickness of the filter will depend upon the kilovoltage employed, but external filtration of *at least* 2 mm. of aluminum is recommended.

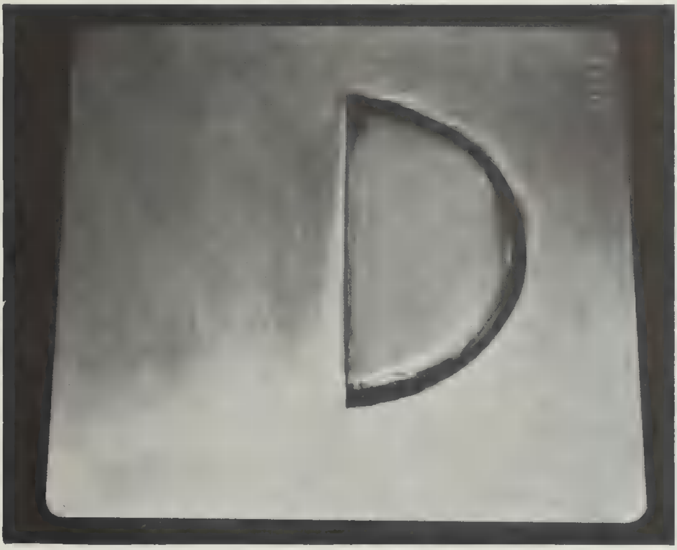
It has long been customary to use a 2 mm. aluminum filter in medical radiography. Such a filter is known to remove some of the *softer* x-rays which would be almost completely absorbed in the patient, and would be of no value to the radiographic image. Radiation of this nature, absorbed by the patient, contributes to his radiation dosage. Trout and his co-workers studied the effect on radiographic contrast of various amounts of filtration and the corresponding reduction in the patient dosage. They found that from 1 to 3 mm. of aluminum could be used, depending on the body part, without detrimentally affecting the radiographic image quality.

Gianturco, Miller, and Wenks use 2 mm. of aluminum up to 50 Kv.P., 4 mm. between 50 and 90 Kv.P., and 6 mm. between 100 and 120 Kv.P.

The author has found 3 mm. total filtration to be adequate up to 100 Kv.P., and the resulting radiographs of superior quality to those in which 1 or 1½ mm. of aluminum was used. No additional adjustments in milliampere-seconds were required except in chest radiography at 80 Kv.P., for regular film in a cardboard holder for extremities, and low-voltage infant extremity techniques.

According to Trout, Kelley, and Cathey, added filtrations of up to 2 mm. of aluminum at voltages up to 70 Kv.P., and above 70 Kv.P. 3 mm. or 0.1 mm. of copper, produce no significant changes in the radiograph. They state further, "At 130 Kv.P. and thick parts even 0.25 mm. of copper does not alter the roentgenogram."

Figure 4.5 An opaque plastic filter.



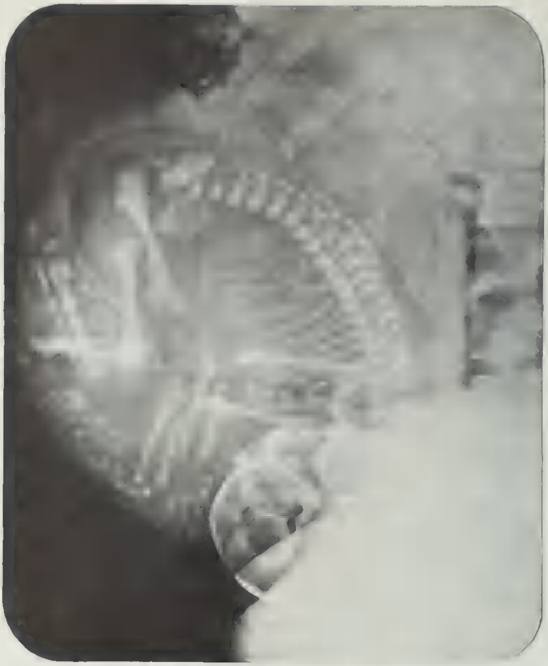


Figure 4.6 Lateral soft-tissue radiographs of a pregnant uterus, taken with a barium plastic filter.

Compensating filters

It may be desirable to render detail visible in all parts of a subject having wide variations of thickness. If the exposure is selected to give a usable density with the thin part, the thick region may be underexposed. If the exposure is selected to give a suitable density with the thick part, the image of the thin part may be grossly overexposed. This may be overcome to some extent by the use of a high kilovoltage technique or the use of a barium plastic filter.

The use of barium plastic or opaque plastic makes it possible to select an exposure which will give the penetration necessary for the heavier parts, and also, through absorption by opaque plastic, will give satisfactory images of the part requiring less penetration.

The less dense area of the part to be examined is radiographed through the semi-opaque material so that the entire area is uniformly represented on the finished radiograph.

In most cases of radiography, opaque plastic is more selective since *copper* transmits x-rays of the *shorter wave lengths;* consequently, the radiographs have a tendency to be low in contrast. Filters made of *aluminum* transmit more of the *longer wave lengths;* hence the radiographs are higher in contrast when employing identical technical factors.

Opaque plastic has an oil base, does not dry out, and may be used repeatedly.

The plastic filter may be used in radiography of the foot in the anteroposterior position, os calcis, lateral cervicodorsal spine, lateral lumbodorsal spine, posteroanterior chest where pathology is present on one side, coccygeal canal, and placenta radiography.

An increase in exposure or kilovoltage is normally required to compensate for the additional absorption, but in cases where the filter method is applicable, this is not serious unless the limit of the x-ray tube has been reached.

Directions for making opaque plastic

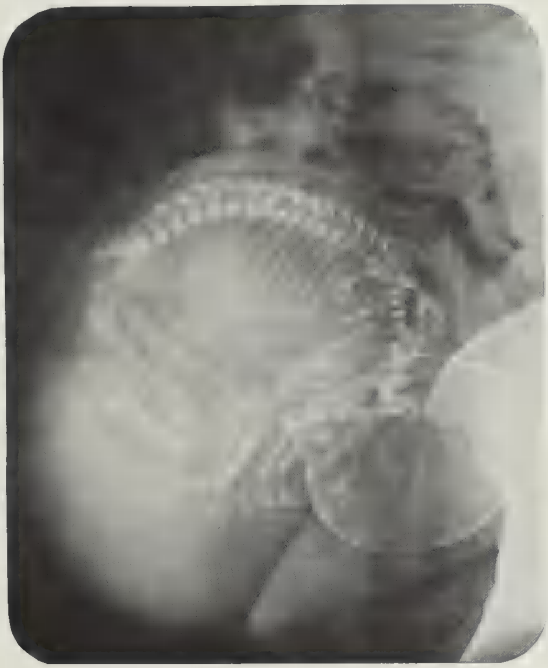
Material required. Petrolatum, balsam of fir, barium sulfate.

Procedure. Heat petrolatum to a few degrees above melting point. To 1 lb. of petrolatum add 6 c.c. balsam of fir, and mix well. Sift barium sulfate slowly into this mixture, mixing it until it is possible to remove a part of it in the hand. Now knead more barium into this until it has a consistency somewhat stiffer than that of putty. Enough barium should be kneaded until the material will not stick to newsprint. It must be noted that very active kneading is required in order to produce a smooth mixture – one that has an even distribution of barium throughout.

THE POTTER-BUCKY DIAPHRAGM

The grid diaphragm was invented by Gustav Bucky in 1913; however, it was not very practical since it was used in a stationary position. Dr. Hollis Potter made the Bucky practical by moving the grid during the radiographic

Figure 4.7 Lateral soft-tissue radiographs of a pregnant uterus, taken with a barium plastic filter.



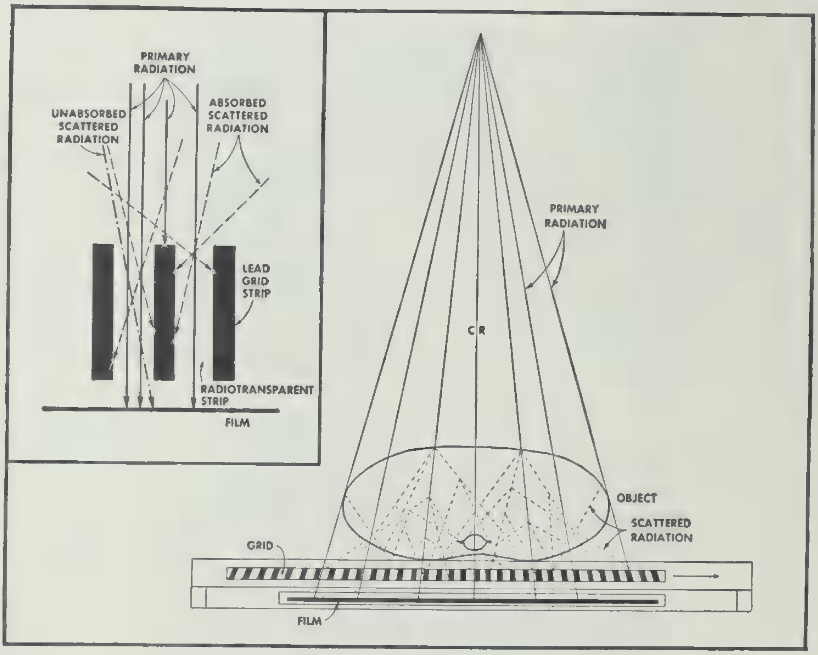
exposure, a procedure that blurred the grid lines out of the image. The grid has since been known as the Potter-Bucky diaphragm.

A series of articles published in the early thirties by R. B. Wilsey presented the results of quantitative determinations of the proportion of scattered radiation in the radiography of a water phantom, under a variety of combinations of thickness, kilovoltage, and field size. These papers, which are considered classics in their field, showed an increase in scatter with increase in each of these three variables.

In 1949 Trout, Graves, and Slauson published a paper in which they showed the effect of the use of high-ratio grids on radiographic contrast at the higher kilovoltages. This work was undertaken because of the increasing interest in extending the kilovoltage range up to 130 Kv.P. Because of their greater efficiency in the removal of the scattered radiation, the use of high-ratio grids made possible the production of radiographs of satisfactory contrast at high kilovoltage, and at the same time reduced tube loads and radiation dosages to the patient.

There is, however, a limit to the advantages gained by grids and the use of higher kilovoltages. Wilsey showed that the exposure of the normal adult chest of medium size is formed by about 45 per cent primary radiation and 55 per cent scattered radiation. This fact led Seemann and Splettstosser to do research on subject contrast employing an 8-to-1 and a 16-to-1 grid.

Figure 4.8 Left, detail of a grid. Note how a large proportion of the scattered radiation is absorbed, but image-forming radiation passes through. Right, diagram of a Potter-Bucky diaphragm.



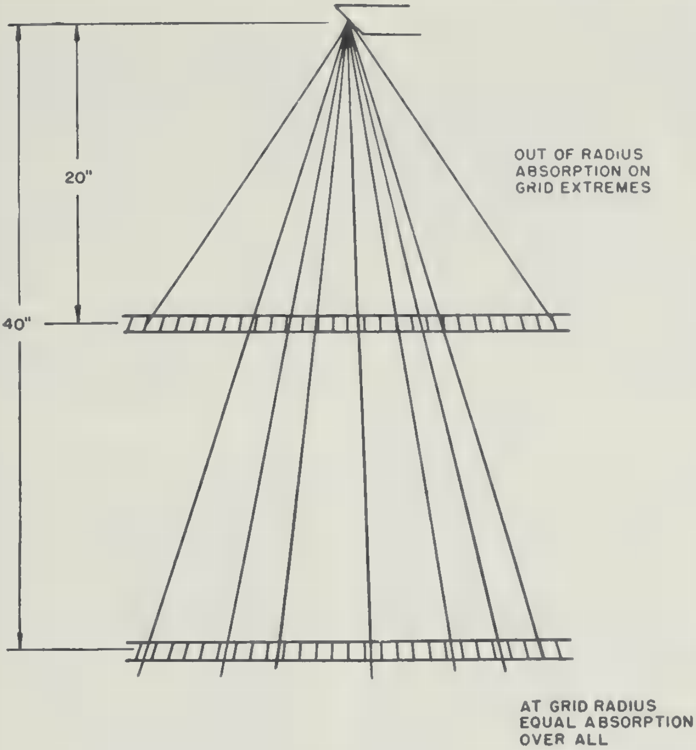

20"
40"
OUT OF RADIUS ABSORPTION ON GRID EXTREMES
AT GRID RADIUS EQUAL ABSORPTION OVER ALL

Figure 4.9 The effect of grid radius and distance on absorption.

They found by employing a 5.7 cm. phantom which approximated the normal chest, that in subject contrast, and with such relatively small amounts of scattered radiation, an 8-to-1 grid is almost as useful as a 16-to-1 grid. The 16-to-1 grid should be employed only when it offers a significant advantage by increasing subject contrast. Several types of examinations in which higher kilovoltage (120 Kv.P.) and 16-to-1 grids have been widely accepted are pregnancy studies and gastrointestinal, colon, and lateral lumbar spine radiography.

Since the first grid was built in 1913, Bucky's principle of *lead foil* strips standing on edge separated by x-ray-transparent interspacers has remained the only known way to trap the secondary or scattered radiation.

Crossed grid for Potter-Bucky diaphragm

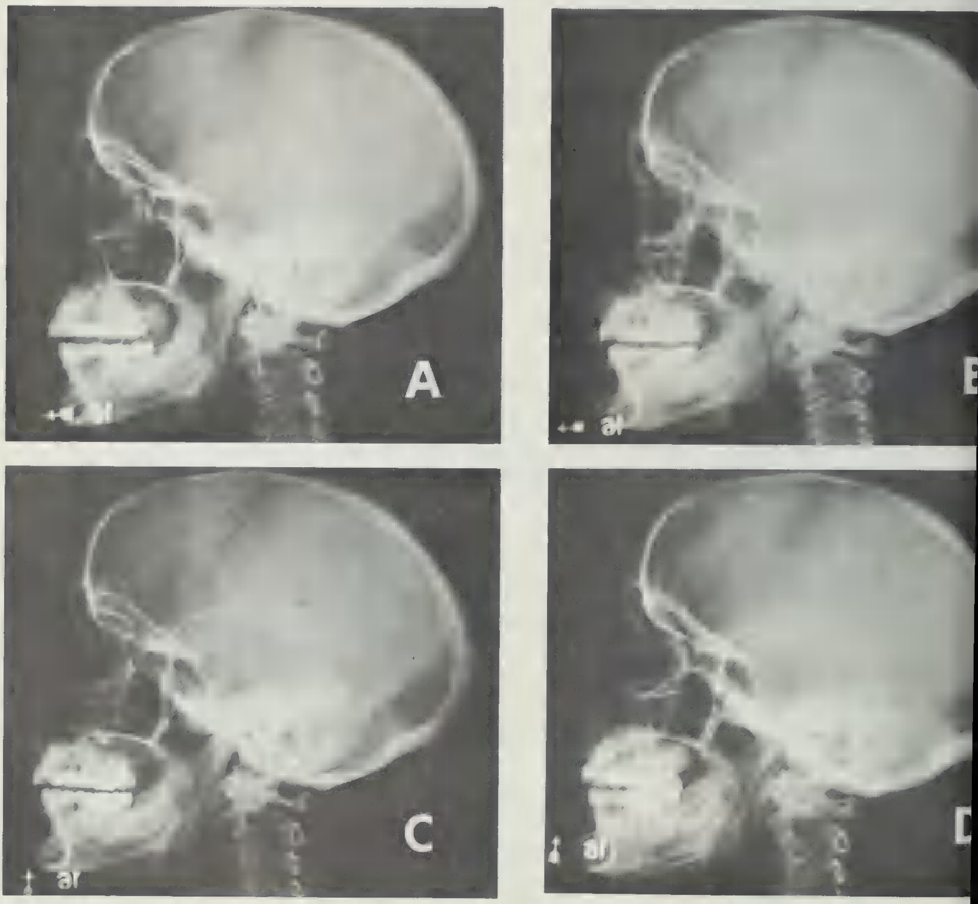
The Liebel-Flarsheim Company is now manufacturing a crossed grid for use in its Recipromatic Potter-Bucky Diaphragm. This crossed grid equals the 16-to-1 ratio linear grid for clean-up and freedom from grid pattern, yet allows generous positioning latitude. It is especially good for high kilovoltage work. Its only contra-indication is for angled techniques. This is the first full size cross-hatch grid for Bucky radiography and is available in focus-film distance ranges of 34 to 44 inches, and 48 to 72 inches, at 80 lines per inch. The actual ratio is 8 to 1 with an effective ratio of 16 to 1 plus.

Grid cut-off

There are certain restrictions one must observe when employing a grid. These restrictions concern the *centering* of the x-ray tube, *direction* of stereo-shift, direction and degree of *tilt* of the x-ray beam, and the choice of *focus-film distance*.

All of these factors are involved with the direction of the primary beam in its passage through the grid. Ratio governs the amount of restriction placed on the technologist. A low-ratio grid is easy to work with because some off-centering and distance change can be tolerated, while a high-ratio grid requires very precise centering and operation only at the focal distance of the grid.

Figure 4.10. Radiographs of skull made in stereo with a 16-to-1 grid, A and B with a crosswise shift, and C and D with an up-and-down shift.



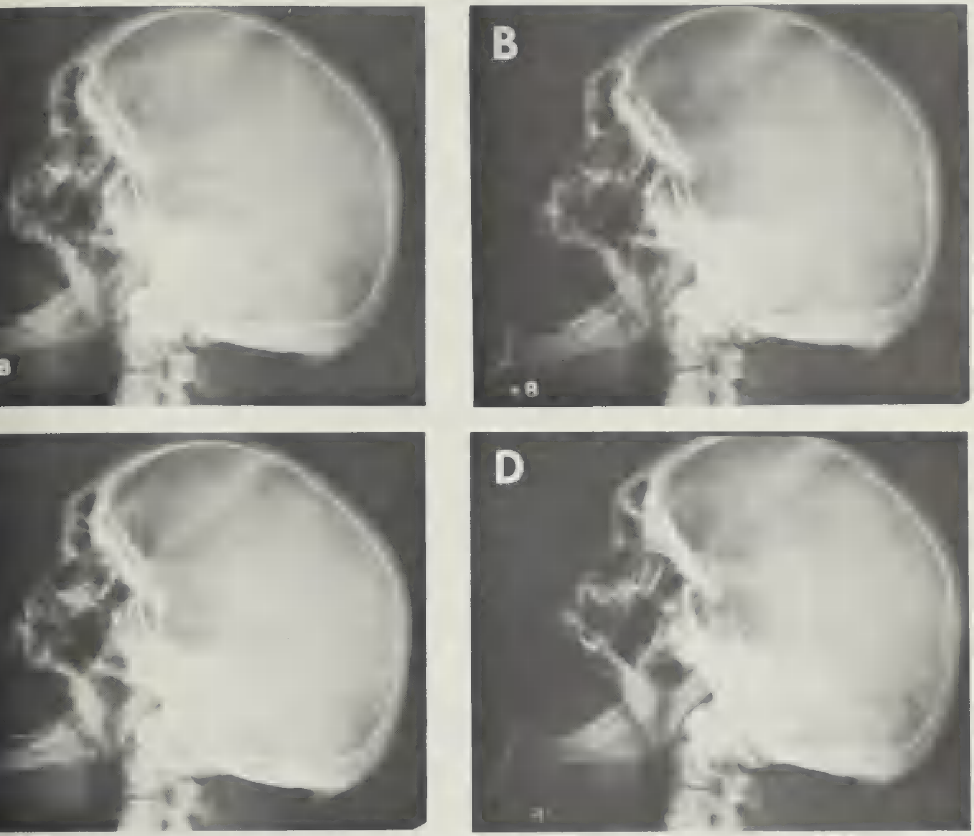


Figure 4.11 Radiographs of the skull made with an 8 to 1 grid, A and B with a crosswise shift, and C and D with an up-and-down shift.

The ratio of a grid is defined as the *relation of the height of the lead strips to the width between them.* Thus, with interspacers 8 times as high as they are wide, a grid is said to be 8-to-1 ratio.

Stereo shift and grids

With a 5-to-1 or 6.5-to-1 ratio Bucky grid, one may stereo-shift across the grid strips. Tube centering is not critical, and the focus-film distance can be changed through a reasonable range. As grid ratio increases, cross-shift stereoscopic exposures become difficult. The difficulty is in *matching* the density of the two films of the stereo pair. It is recommended that cross-table stereo-shifting be abandoned when using an 8-to-1 ratio grid. When a 16-to-1 ratio grid is used, cross-shift stereoscopic radiography is impossible. The radiographic tube must be centered precisely over the midline of the table and focus-film distance must be fixed at the focal distance of the grid. Whenever an underexposed radiograph results from a technique that has been giving consistent results with a 16-to-1 grid, always check the *tube*

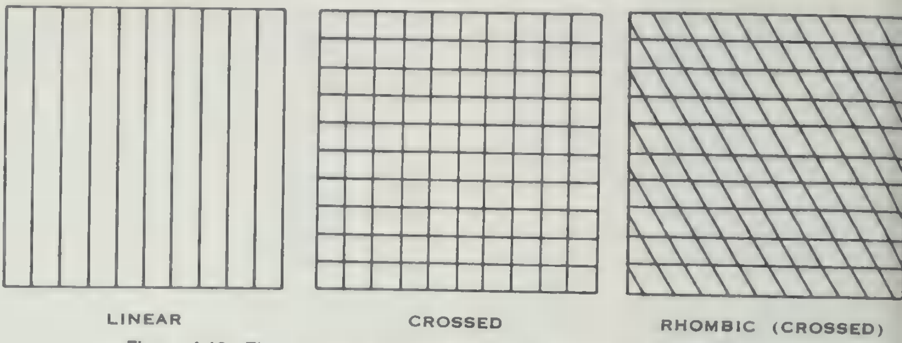


Figure 4.12 Three common grid patterns - linear, crossed, and rhombic.

centering. The tube may have been "off center" to account for the underexposure.

Linear grids vs. cross-hatch. The term "linear" refers to a grid that has lead lines running in only one direction. Linear grids are very popular and versatile.

If cross-hatch grids are used, it is impossible to tilt the tube more than just enough to accomplish a stereo-shift in either direction. Cross-hatch grids are normally used for high kilovoltage at a fixed distance and the central ray aligned at 90° to the grid surface.

Figure 4.13. Radiograph showing grid cut-off on the left side.

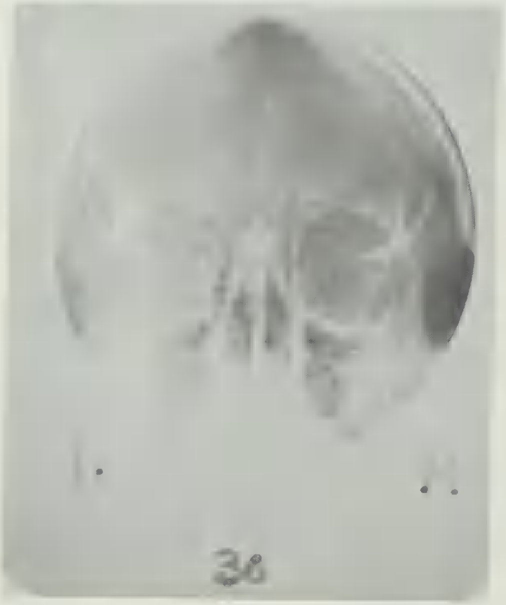
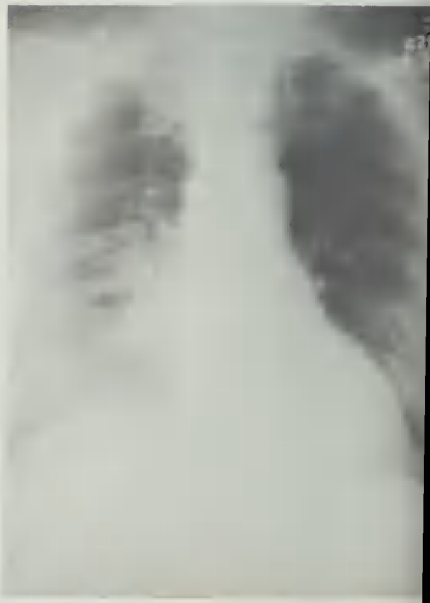


Figure 4.14 In this radiograph, there is grid on the right side of the chest due to improper ment of the grid and the central ray.



Off-distance cut-off. Off-distance cut-off occurs when a grid is used at a focus-film distance greater or less than the focal distance of the grid. It appears on the radiograph as areas of *decreased* density along the outside edges of the film or on the fluoroscopic image.

STATIONARY GRID

The stationary grid is a modern application of the original Bucky principle – elimination of secondary radiation by means of a mechanical grid placed between the film and the body part being examined. There are numerous applications where there is need for elimination of secondary x-ray but where the Potter-Bucky diaphragm cannot be employed. The stationary grid is used for fluoroscopy, portable radiography, spot-film radiography, and unusual techniques, such as large chest radiography, and lateral cervical spine radiography which requires target-to-film distances above the limits of regular Potter-Bucky diaphragms.

Stationary grids are of two types, *parallel* or *focused*. In the parallel grid the lead strips are not angulated; it is used where the film is of limited width or where the target-to-film distance is great. Any application requiring the use of a wide film at moderate target-to-film distance calls for the use of a focused grid in which angulation of the lead strips is present. The focused grids are aligned for either 30- or 36-inch focal distance.

4.15. Chest radiograph of a large patient, ithout a grid.

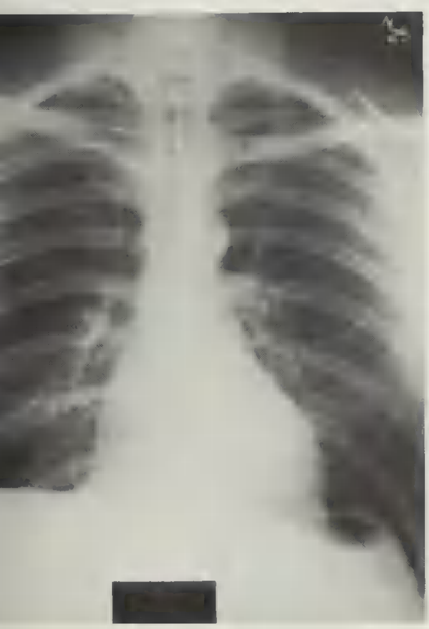
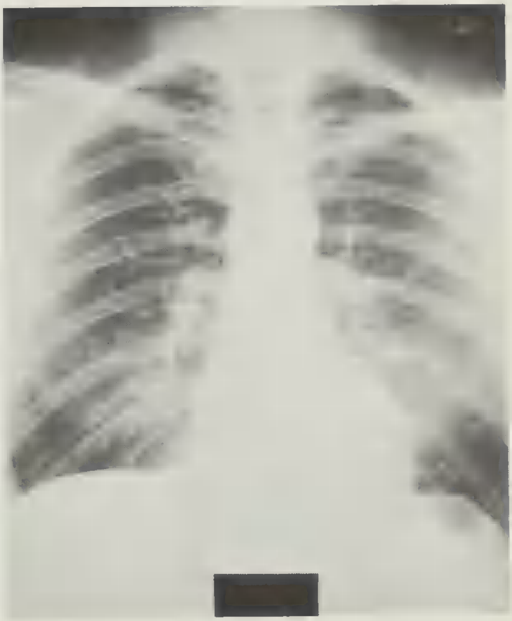


Figure 4.16 Radiograph of the patient of Figure 4.13, made with a grid cassette.



SELECTION OF A GRID

The selection of a grid to be used for a particular radiograph will be primarily dependent on the following considerations:

1. Relative quantity of secondary radiation produced by subject being radiographed.
2. Kilovoltage technique to be used.
3. Capacity of x-ray generator.

The quantity of secondary radiation produced is dependent on the thickness and relative density of the body volume being radiographed. A non-grid exposure of the chest will consist of about one-half secondary radiation, while a non-grid exposure of the abdomen may consist of more than 90% secondary radiation. From this, it is apparent that for dense body sections the more effective remover of secondary radiation will provide the most striking improvement in the radiograph, and this suggests the use of a high-ratio grid or a crossed grid. The choice between these two grids depends on the ease of aligning the grid correctly relative to the x-ray tube, and whether a high- or low-kilovoltage technique is to be used. If there is any question of the possibility of proper centering and leveling, or if low kilovoltages are to be used, the crossed grid of 5:1 ratio will present much greater advantages from the standpoint of positioning latitude and cleanup. For high-kilovoltage techniques, particularly if the grid can be accurately aligned or if it is mounted in a Potter-Bucky Diaphragm, greater advantages will be gained with the high-ratio linear grid or an 8:1 ratio rhombic grid. (Crossed grids are not recommended for the techniques that require angling of the x-ray tube.)

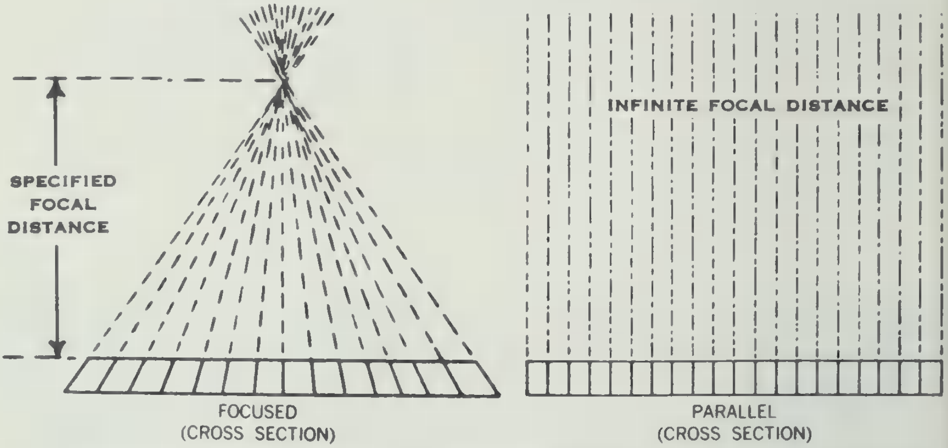


Figure 4.17 Cross sections of two grid arrangements: at the left, a focused grid, with progressively angled leads; at the right, a parallel grid.

At kilovoltages of the order of 100 Kv.P. or more, comparable photographic

Table 4.1 GRID CHARACTERISTICS

Type of grid	*Features and uses*
4:1 ratio, linear (low dose)	Special grid for use in image intensification and spot-filming. It offers adequate cleanup for small coned-down areas, combined with relatively small patient dosage.
5:1 ratio, linear	Moderate cleanup. Extreme latitude in use. Use at lower kilovoltages (up to 80 Kv.P.) wherever wide latitude is desired. Very easy to use.
5:1 ratio, crossed	Very high cleanup, especially at lower kilovoltages. Extreme latitude in use. Use up to 100 Kv.P. wherever wide latitude and excellent cleanup are desired. Very easy to use. Not recommended for tilted-tube techniques.
6:1 ratio, linear	Moderate cleanup. Good positioning latitude. Easy to use.
8:1 ratio, linear	Better cleanup than 5:1 linear. Fair distance latitude. Little centering and leveling latitude. Use up to 100 Kv.P. where wide latitude is not required.
12:1 ratio, linear	Better cleanup than 8:1. Very little positioning latitude. Use for both low and high kilovoltage techniques (up to 110 Kv.P. or slightly higher). Extra care is required for proper alignment in use. Usually used in a fixed mount or Potter-Bucky diaphragm.
16:1 ratio, linear	Very high cleanup. Practically no positioning latitude. Intended primarily for use above 100 Kv.P. in a Potter-Bucky diaphragm. Excellent for high-kilovoltage radiographs of thick body sections.
8:1 ratio, crossed	Extremely high cleanup. Superior to 16:1 ratio linear grid at kilovoltages up to 125. Positioning latitude equivalent to 8:1 ratio linear. Not usable for tilted-tube techniques.
10:1 ratio, 133 line, linear	Special grid for maximum line invisibility. Cleanup similar to 8:1 linear. Very little positioning latitude. Extra care is required for proper alignment in use. Best grid to use stationary in a table to replace the moving Bucky grid.

effect requires lower Ma.S. values than at low kilovoltages to keep the radiation dosage to the patient low. However, in order to maintain the same contrast range at the higher kilovoltage, it is necessary to use a grid of higher ratio. The exposure factors are not the same for all ratios, and the increased exposure required for a high-ratio grid may to some extent reduce the patient-dosage advantage gained by going to high-kilovoltage techniques. In general, in spite of the higher exposure factors involved, the use of high kilovoltage and high-ratio grids will result in somewhat lower radiation dosage to the patient.

All radiographers must work within the limitations of the physical characteristics of the x-ray equipment at their disposal. While this may not be as important a consideration in the selection of a grid as some others, it is a

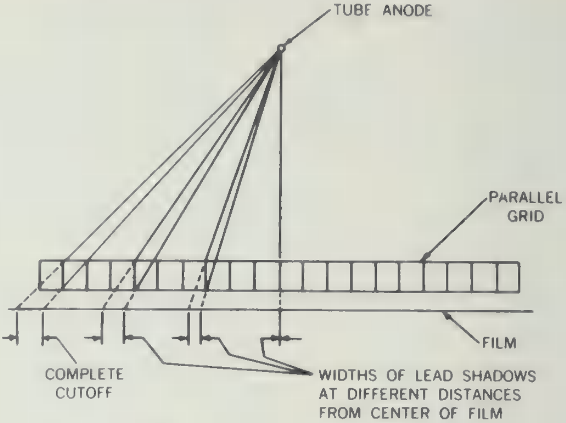
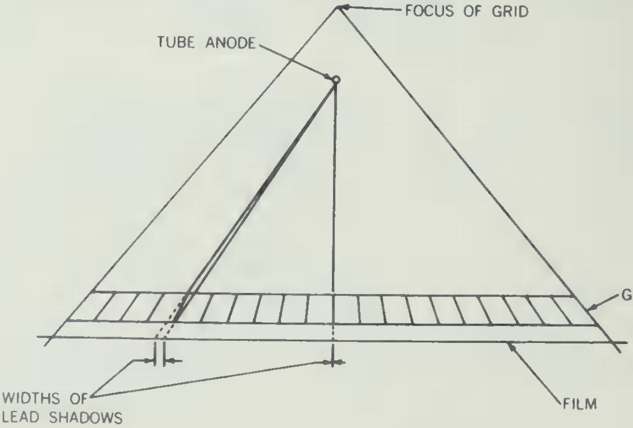

TUBE ANODE
PARALLEL GRID
FILM
COMPLETE CUTOFF
WIDTHS OF LEAD SHADOWS AT DIFFERENT DISTANCES FROM CENTER OF FILM

Figure 4.18 Primary cutoff in a parallel grid.

factor to be considered. For instance, the maximum benefits to be derived from a 16:1-ratio grid will not be realized with a unit whose top limit is 90 Kv.P., although there will be some advantages over a lower-ratio grid. In general, a 16:1-ratio grid will do the most good with equipment which can be used at kilovoltages above 100 Kv.P. This applies also, to a lesser extent, to the 12:1-ratio grid. With a bedside or portable unit, where the likelihood of near-perfect alignment of the grid relative to the primary beam is poor, the use of the high-ratio grids is practically impossible, and difficulties may be encountered even with the 8:1-ratio grids. For such use, where wide latitude in distance, centering, and leveling is necessary, the 5:1-ratio grid is advisable, and for maximum cleanup under these conditions the 5:1 crossed grid is ideal.

Figure 4.19 Off-distance cutoff in a focused grid.



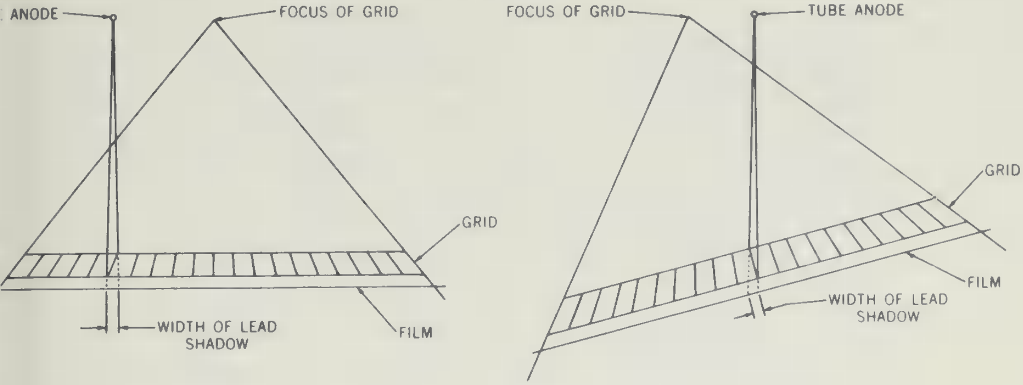


Figure 4.20. Off-center and off-level cutoff in a focused grid.

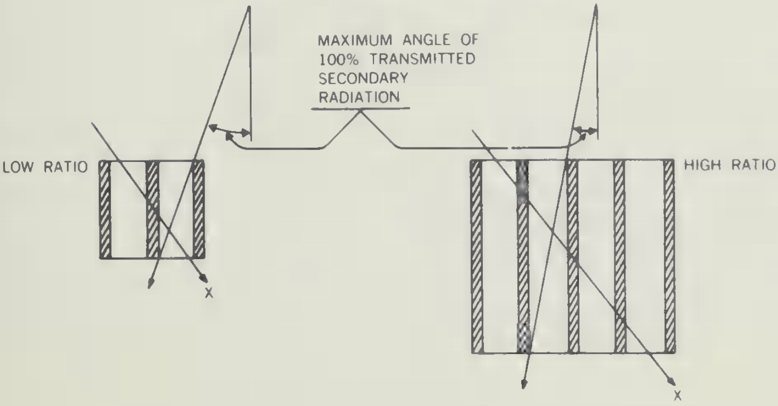
Faulty use of grids

A primary cutoff can easily occur with a parallel grid. As may be seen in Figure 4.18, only the leads directly under the tube anode in a parallel grid throw shadows no wider than themselves on the film. All other leads in the grid make shadows which are wider than the thickness of the lead by amounts proportionate to their distances from the centerline. This cutoff of primary radiation results in progressively decreased density as the edge of the film is approached. Compensation through tapering grid thickness toward the edges (prismatic focus) is undesirable because grid ratio decreases and effectiveness is lost beyond the center portion of the film.

In off-distance cutoff in a focused grid (Figure 4.19) the effect is much the same as when a parallel grid is used; i.e., there is a progressive decrease in density as the edge of the film is approached. However, if the grid is used within its specified focal range this effect should not be objectionable.

In off-center and off-level cutoff (Figure 4.20) the effect is somewhat different than with tube off-distance. Since all the leads are out of correct alignment with the primary rays, the entire film will show a lighter density than it should with proper alignment of the grid. Local misangulations in the

Figure 4.21. The effect of ratio on cleanup.



grid are also much more apparent when it is used off-center or off-level. These conditions should be carefully avoided with grids of 8:1 ratio or higher.

Care is also worth taking to compensate for the effect of grid ratio. In Figure 4.21 radiation at angle X will be more attenuated by passing through more leads in the high-ratio grid than in the low-ratio. The maximum angle of fully transmitted secondary radiation will also be smaller for a high-ratio grid than for a low-ratio grid. This clearly indicates why high-ratio grids remove more scatter and require increased exposure.

STEREORADIOGRAPHY

An ordinary photograph made with a camera shows perspective: the relative positions and sizes of the various objects shown in the photograph are readily apparent. This is not true of a radiograph because it is a shadow picture of overlying parts having various opacities to x-ray. The single radiograph does not necessarily show the depth in the structures.

Stereoradiography is relatively simple for all modern x-ray machines and almost any region of the body may be stereoradiographed with little effort; however, two requirements must be kept in mind: namely, perfect positioning and complete immobilization. Stereoscopic vision is directly dependent upon the definition in the radiographic images as well as the degree of stereoscopic shift and a moderately long anode-film distance (36 inches) for creating a greater depth of focus.

Stereoscopic films are made by exposing two films; the part of the body and the film are in exactly the same position, but with a different position of the anode of the tube for each exposure. In stereoscopic views of the chest the plate must be changed without disturbing the part, and this is provided for by the use of a cassette changer.

In exposing stereoscopic films the distance and direction of the shift of the tube between the two exposures are both of considerable importance. Normally the distance of the tube is controlled by the construction of the stereoscope in which the films are to be examined; using a stereoscope with a 25-inch distance between the mirrors and the view boxes, a 2½-inch stereo shift would be required. *Generally speaking, the tube shift in stereoscopic radiography should be 10 per cent of the anode-film distance.*

The direction of the tube shift in exposing stereoscopic film is controlled by the direction of the predominating lines in the parts being radiographed. The tube shift should be as nearly as possible at right angles to the line. In the thorax the predominating lines are the borders of the ribs; therefore, the tube shift should be along the vertebral column. In making films of the long bones, the shift should be across the bones; for those of the skull it may be in either direction, depending on which structures are to be investigated. In exposing stereoscopic films, the parts to be radiographed are placed in position as for a normal single radiograph. For the first film from the center position, the tube is moved in the proper direction one-half of the distance of the shift. It is now in position for the exposure of the first film, and when this has been made, the tube should be moved past the center position an equal distance and the second film exposed.

Stereoradiography: accessory nasal sinuses

Caldwell projection. In the posteroanterior projections of the sinuses, it is important that the stereoscopic shift be made vertical and *front to back* and *never crosswise,* in order to prevent overshadowing of the anatomy of interest by the oblique projection of adjacent structures.

The normal Caldwell projection should throw the shadow of the petrous portion of the temporal bone in the upper portion of the maxillary sinuses.

Waters projection. When using the Waters projection for the maxillary sinuses, the shadow of the petrous portions of the temporal bone should be thrown below, or caudad to the antra. The tube shift should be made toward the top of the head (cephalad), so the antra will be free of superimposed structures.

Lateral projection. In the lateral projections, the tube shift may be horizontal or vertical.

Sphenoid, open-mouth projection. The tube shift should be horizontal (cephalad).

THE ANODE HEEL EFFECT

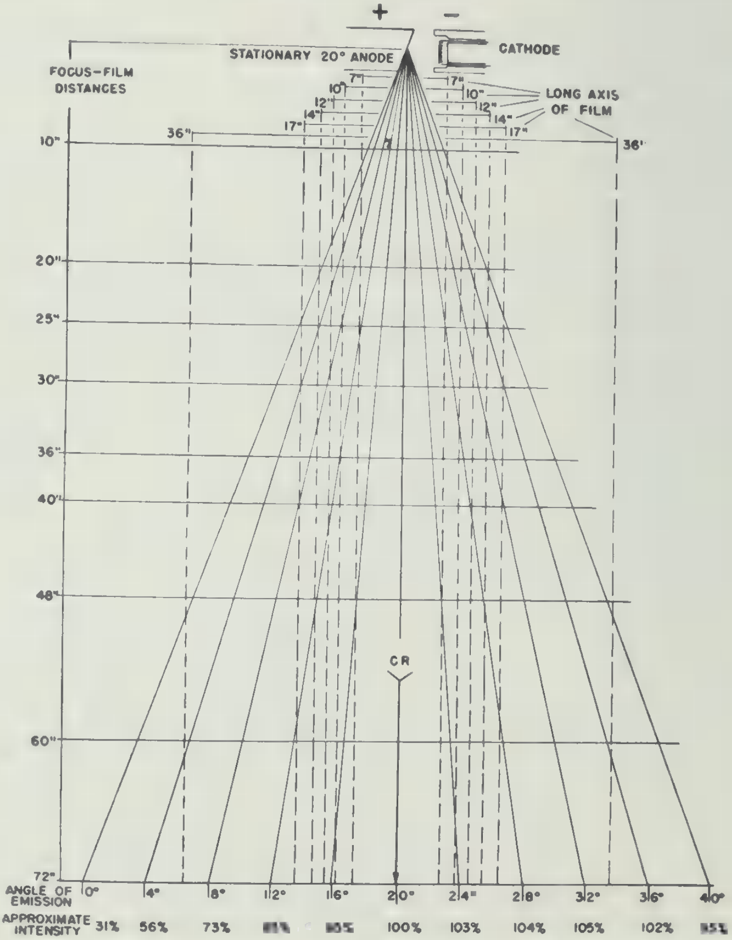
Various investigators have drawn attention to the angular distribution of radiation intensity from the anode face. Experiments have been described in which ionization measurements were made of the intensities emitted at various angles. The results were illuminating: a wide range of intensities that could have positive radiographic effect was demonstrated. But little more than academic interest has been awakened for applying this inherent characteristic of all x-ray tubes—the "heel effect"—to influence balanced radiographic densities in the image. It must be understood that evidence of the heel effect does not signify a tube fault, for it is an advantageous characteristic of all x-ray tubes and is an invaluable means toward producing balanced radiographic densities.

Unexplainable radiographic density differences which could not always be attributed to the incorrect use of exposure factors have annoyingly occurred on radiographs in many x-ray departments. These annoyances have been largely attributable to improper alignment of the tube to the part so that the heel effect could not be properly employed.

The heel effect is a variation in x-ray intensity output (depending upon the angle of x-ray emission from the focal spot) along the longitudinal tube axis and in relation to the long axis of a film. The intensity diminishes fairly rapidly from the central ray toward the *anode* side of the x-ray beam; on the cathode side of the beam, intensity increases slightly over that of the central ray. Generally the heel effect is limited in its application at long focus-film distances. When average or short distances are used on large film areas, its effect is most advantageous, particularly where decided differences in tissue densities require balancing of radiographic densities to avoid over- and underexposures within the same image.

The approximate percentage of x-ray intensity emitted by a tube at various angles of emission may be determined directly from photometric measurements of the radiographic blackening of an x-ray film. For radiographic purposes, this procedure is adequate and gives an indication of the approximate percentage of quantity variation to be expected when the x-ray beam falls on specific areas of different sizes of x-ray films at various focus-film distances. Figure 4.22 graphically represents the mean values of radiographic density measurements obtained from many intensities emitted by various x-ray tubes. This diagram, drawn to scale, shows radii emanating from the target face, drawn at 4° intervals from 0° to 40° and intercepting horizontal lines representing various focus-film distances. At the termination of the radii at the bottom of the chart, the mean density values in percentages are indicated. For convenience, the radiographic density caused by the central

Figure 4.22. The anode heel effect.



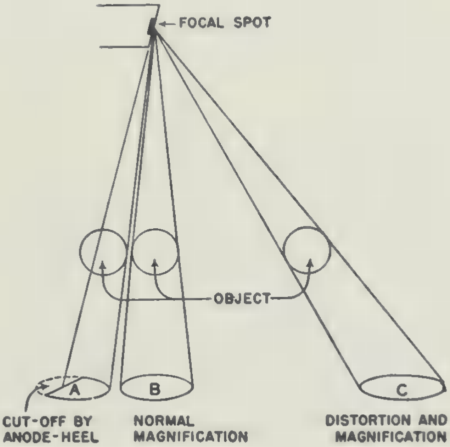
ray (CR) is figured as 100 per cent. To the left or anode side of the central ray, the densities diminish in value, while those to the right or cathode side increase moderately and then decrease slightly.

The spaces between the vertical dotted lines beginning just below the diagram of the anode and terminating at the 72-inch focus-film distance line, when approximately paired, indicate the length of each size of film and the approximate location at various focus-film distances of the respective density values created by the intensities of radiation at various angles of x-ray emission. For example, on the 48-inch focus-film distance line the outermost pair of vertical lines representing the 36-inch length of film passes outside the limits of the x-ray beam. In order to make use of the entire range of intensities on this length of film, it would be necessary to employ a focus-film distance of 49 inches. All intensity radii would intercept at this distance; consequently, if an exposure were made, the entire range of intensities would be expected to become evident, let us say, on a radiograph of an entire spine. Since the minimal intensity in the anode portion of the beam, approximately 31 per cent, is emitted in advance to the angle indicated as 0°, it is obvious that the portion of the spine having least tissue density (the neck) should be exposed by this portion of the beam and the heavier portion (the lumbar vertebrae) by the cathode portion of the beam.

When radiographs on large film are made at relatively short focus-film distances, a knowledge of the distribution of the intensity in approximate percentages delivered to a particular size of film at a known focus-film distance is indispensable to correct alignment of the tube and part to the film at the most favorable focus-film distance. Radiographic densities cannot be balanced if only the intensity of the central ray is considered.

Radiographs are often secured in which a certain area of the image is definitely underexposed while another is overexposed, even though the factors seemed adequate for the tissue-density traversed by the central ray.

Figure 4.23. Limiting factors in short-focus radiography on large film sizes.



This condition usually occurs when improper alignment of the tube relative to the part takes place. This lack of balance between radiographic densities is typical of the heel effect of the anode when it is improperly applied.

The general rule for utilizing the heel effect is as follows: *Align the long axis of the tube parallel with the long axis of the part to be examined and direct the cathode portion of the beam toward the anatomic area of greatest tissue density.*

Chapter 5. SIMPLIFIED MATHEMATICS FOR RADIOGRAPHY; BASIC EXPOSURE EXPERIMENTS

A great many problems in radiography can be reduced to mathematics. Technique problems and conversions can be quite accurately calculated. Such calculation represents a much more scientific approach to radiographic technique than the old "hunch method" of radiography. This chapter of simple arithmetic is intended to refresh the student's mind on the fundamentals that are essential for the proper understanding of the modern physical principles of radiography. It is taken for granted that the student technologist has had an elementary course in high school mathematics.

FRACTIONS

A. A fraction has a numerator and a denominator. The number above the line is called the numerator and the number below the line, the denominator.

Example: In the fraction $^3/_4$, the number 3 is the numerator, and the number 4 below the line is the denominator. This fraction, $^3/_4$, indicates that 3 is being divided by 4.

B. In multiplying fractions, take the product of the numerators and place it over the product of the denominators and then simplify this new fraction.

Example:

$$^3/_4 \times {^4/_5} = \frac{3 \times 4}{4 \times 5} = \frac{12}{20}$$

C. To reduce, simply divide the numerator and the denominator by the same number.

Example:

$$\frac{12}{20} = \frac{6}{10} = \frac{3}{5}$$

D. In computing Ma.S. values, it is often convenient to use the decimal equivalent of the fractional exposure.

Example:

$^5/_8$ second would be: .625. See Table 6.8 below.

E. The word "of" is often used to mean "multiply."

Example:

$$^1/_2 \text{ of } {^1/_2} = {^1/_2} \times {^1/_2} = {^1/_4}$$

EQUATIONS

In solving equations we place the unknown on the left and solve for the unknown first.

Example:

$$\frac{a}{b} = \frac{c}{d} \qquad \text{Find } a$$

$$a = \frac{bc}{d}$$

This means *a* is equal to *b* times *c*, divided by *d*.

If a letter or number from the right is taken, we place it on the lower left and the letter or number on the bottom left goes to the upper right.

Example:

$$d = \frac{bc}{a} \qquad c = \frac{ad}{b}$$

DECIMALS

A decimal, which is a number with a decimal point (.), is actually a fraction, the denominator of which is understood to be 10 or some power of 10.

A. The number of digits, or places, after a decimal point determines which power of 10 the denominator is. If there is one digit, the denominator is understood to be 10, etc.

Example:

$$.7 = {}^{7}/_{10},\ .39 = {}^{39}/_{100},\ .727 = {}^{727}/_{1000}.$$

B. The addition of zeros after a decimal point does not change the value of the decimal.

Example:

$.9 = .90 = .900$ and vice versa,

$.900 = .90 = .9$

C. Since a decimal point is understood to exist after any whole number, the addition of any number of zeros after such a decimal point is written in does not change the value of the number.

Example:

$6 = 6.0 = 6.00$, etc.

PERCENTAGES

The per cent sign (%) is a symbol used to indicate percentage, but no operations can be performed with the number to which it is attached. For convenience, then, it is sometimes required to attach a per cent sign, but to perform operations with the number, it is necessary to remove the sign.

A. In general, to remove a per cent sign, divide the number by 100.

Example:

$$900\% = 9$$

B. A per cent may be expressed as a decimal or a fraction by dividing it by 100.

Example:

$$43\% = .43$$

$$7\% = {}^{7}/_{100} \text{ or } .07$$

C. A decimal may be expressed as a per cent by multiplying it by 100.

Example:

$$.39 = 39\%$$

RATIO

A. A ratio expresses the relationship between two (or more) quantities in terms of numbers. The mark used to indicate ratio is the colon (:) and is read as "is to."

Example:

The ratio 6:7 is read "6 is to 7."

B. A ratio represents the function of division. Therefore, any ratio of two terms may be written as a fraction, and any fraction may be written as a ratio.

Example:

$$7 : 8 = {}^{7}/_{8}$$

$${}^{2}/_{5} = 2 : 5$$

C. To simplify any complicated ratio of two terms containing fractions, decimals, or per cents:

1. Divide the first term by the second.
2. Convert to a ratio.

Example:

Simplify the ratio ${}^{5}/_{6} : {}^{7}/_{8}$

Solution:

$${}^{5}/_{6} \div {}^{7}/_{8} = {}^{5}/_{6} \times {}^{8}/_{7} = {}^{20}/_{21}$$

$${}^{20}/_{21} = 20:21$$

D. There are two main types of ratio problems:

1. Problems in which the ratio is given.
2. Problems in which the ratio is implied, but not given.

E. To solve problems in which the ratio is given:

1. Add the terms in the ratio.
2. Divide the total by this sum.
3. Multiply each term in the ratio by this quotient.

Example: A man bought three X-ray machines. The first one cost $^1/_4$ more than the second, and the third $^1/_2$ more than the second. He paid $30,000 for the three machines. How much did he pay for each?

Solution: The basic machine is the second one, which has the ratio value of 1. The first machine cost $^1/_4$ more than the second; therefore its ratio value is $1^1/_4$. The third machine cost $^1/_2$ more than the second, therefore its ratio value is $1^1/_2$.

Ratio of the costs $= 1^1/_4 : 1 : 1^1/_2$
$1^1/_4 + 1 + 1^1/_2 = {}^{15}/_4$
$\$30,000 \div {}^{15}/_4 = \$8,000$
$\$8,000 \times 1^1/_4 = \$10,000$
$\$8,000 \times 1 = \$8,000$
$\$8,000 \times 1^1/_2 = \$12,000$
The first machine cost $10,000
The second machine cost $8,000
The third machine cost $12,000

PROPORTION

A. A proportion indicates the equality of two (or more) ratios, often expressed by the symbol ::.

Example

$2:4 = 5:10 = 6:12$ is a proportion. The meaning of $2:4::5:10::6:12$ is the same.

B. If a proportion contains only four terms, the two outside terms are called the *extremes*, and the two inside terms are called *the means*.

Example: In the proportion $2:3 = 4:6$, 2 and 6 are the extremes, and 3 and 4 are the means.

C. In any proportion of four terms, the product of the means equals the product of the extremes.

Example: Relation between milliamperage and time.

1. *Rule:* The milliamperage (M) required for a given exposure is inversely proportional to the time (T).
2. *Problem:* Suppose that 30 milliamperes (M_1) and an exposure time of $^1/_2$ second (T_1) have been employed, and it is desired to decrease the exposure time to $^1/_{20}$ second (T_2). What milliamperage (M_2) would be required?
3. *Solution:*

$M_1 : M_2 :: T_2 : T_1$

$30 : x :: {}^1/_{20} : {}^1/_2$

${}^1/_{20}x = 15$

$$\frac{x}{20} = \frac{15}{1}$$

$x = 15 \times 20$

$x = 300$

$x = 300$ milliamperes

TRANSFORMATION OR CHANGE IN VOLTAGE

The transformation, or change in voltage, is roughly proportional to the ratio of the number of turns in the two coils of a transformer.

Step-up transformer

The primary coil, which is connected to the alternating supply line of 110 or 220 volts, has relatively few turns; the secondary, which is energized by induction from the primary coil, consists of a great number of turns.

Example: If there are 10 turns in the primary coil and 10,000 in the secondary, an impressed voltage of 100 volts on the primary side would induce 100,000 volts in the secondary circuit, with a corresponding decrease in amperage. If it is assumed that the transformer has an efficiency of 100 per cent, the product of the primary voltage E_1 and the current intensity I_1 is E_1I_1, and this would equal the product of the same factors in the secondary side (E_2I_2). Therefore, with a primary voltage of 100 volts and current of 10 amperes, there would be this hypothetical transformation: electricity of the secondary side would be expressed as 100 kilovolts and 10 milliamperes.

OHM'S LAW

When current is transmitted through a conductor, the current of transmission varies directly as the electromotive force (voltage) and inversely as the resistance (ohmage) of the transmitting circuit.

$$\text{Current} = \frac{\text{Electromotive force}}{\text{Resistance}}$$

In electrical units: $\text{Amperes} = \dfrac{\text{Volts}}{\text{Ohms}}$

In symbols: $I = \dfrac{E}{R}$

I = Intensity of current in amperes

E = Electromotive force in volts

R = Resistance in ohms

If we know the electromotive force and current and want to calculate the resistance, we have:

$$R = \frac{E}{I}$$

Example:

(1) What is the intensity of the current sent through a resistance of 5 ohms by an electromotive force of 110 volts?

$$I = \frac{E}{R} = \frac{110}{5} = 22 \text{ amperes}$$

(2) What electromotive force is needed to send a current of 0.03 amperes through a resistance of 1000 ohms?

$$E = IR = 0.03 \times 1000 = 30 \text{ volts}$$

(3) Through what resistance will 110 volts send a current of 10 amperes?

$$R = \frac{E}{I} \qquad \frac{110}{10} = 11 \text{ ohms}$$

BASIC EXPOSURE EXPERIMENTS

The following experiments may be done on phantoms in order to give a better understanding of the basic principles of radiography. The experiments may be made by the instructor and a wealth of teaching material accumulated, or they may be made with each class in attendance.

By repeating these experiments, the technician will acquire a knowledge of radiographic technique that cannot be gained in any other way.

Experiment 1: Focus-film density relation

Purpose. To demonstrate the relation between focus-film distance and radiographic density.

Theory. Any change in focus-film distance influences the intensity of radiation. The intensity varies inversely as the square of the focus-film distance. Since changes in distance produce changes in intensity, radiographic density changes.

Procedure 1. Make a series of three lateral radiographs of the skull using the following factors.

Film:	Regular 10 x 12
Screens:	Medium 10 x 12
Grid:	8 to 1
Distance:	Variable factor
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	15
Time:	$^{1}/_{10}$ sec.
Ma.:	150
Kv.P.:	85
Development:	Automatic

Variable factors:
Exposure 1: 25-inch FFD
Exposure 2: 36-inch FFD
Exposure 3: 48-inch FFD

Comment. It may be observed that as the FFD increased, the radiographic density decreased.

Procedure 2. Follow the same routine as in procedure No. 1, but radiograph a postero-anterior hand.

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	Variable factor
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	70
Time:	$^{7}/_{10}$ sec.
Ma.:	100
Kv.P.:	50
Development:	Automatic

Variable factors:
Exposure 1: 25-inch FFD
Exposure 2: 36-inch FFD
Exposure 3: 48-inch FFD

Experiment 2: Time-FFD density relation

Purpose. To demonstrate the interrelation of time of exposure and focus-film distance to radiographic density when all other factors are constant.

Theory. The time required for a given radiographic density is directly proportional to the square of the FFD when all other factors are constant.

Procedure. Make these postero-anterior radiographs of the hand employing the following factors.

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	Variable factor
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	50
Kv.P.:	50
Development:	Automatic

Variable factors:	*FFD*	*Time*	*Ma.S.*
Exposure 1:	25 inches	$^{1}/_{2}$ sec.	25
Exposure 2:	36 inches	1 sec.	50
Exposure 3:	48 inches	$1^{8}/_{10}$	90

Comment. The densities of these radiographs are approximately the same, because suitable exposure-time compensation has been made for each FFD change in accordance with the inverse square law.

It is recommended that once an FFD is established for a given projection, it should be considered a constant.

Experiment 3: Milliamperage – FFD density

Purpose. To demonstrate the interrelation of milliamperage and focus-film distance to radiographic density.

Theory. When all other factors are constant, the milliamperage required for a given exposure is directly proportional to the square of the FFD.

Procedure. Make a series of three postero-anterior exposures of the hand, employing the following factors.

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None

Distance:	Variable factor
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	Variable factor
Kv.P.:	50
Development:	Automatic

Variable factors:	*Ma.*	*FFD*	*Time*	*Ma.S.*
Exposure 1:	10	25 in.	2 sec.	20
Exposure 2:	30	40 in.	$1\frac{3}{4}$ sec.	52.5
Exposure 3:	100	60 in.	$1\frac{2}{10}$ sec.	120

If the exact Ma. station listed is not available, use any combination of Ma. and Time to give correct Ma.S.

Comment. As the FFD changes, the Ma. and/or Ma.S. may be used to compensate for the normal loss in density. In routine radiography, however, Ma. should be established as a constant for a given projection whenever possible.

Experiment 4: Influence of Ma.S. on density

Theory. No practical amount of Ma.S. will compensate for inadequate kilovoltage.

Procedure. Make a series of eight radiographs of the hand phantom in the postero-anterior projection.

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	Variable factor
Kv.P.	30
Development:	Automatic

Exposure:	*Ma.S.:*
1	15
2	30
3	60
4	120
5	240
6	480
7	960
8	70 but use 50 Kv.P.

Be sure to check the tube-rating chart before making this experiment.

Comment. Only in radiograph No. 8 exposed for 70 Ma.S. at 50 Kv.P. do we have a *practical amount* of Ma.S. and *sufficient* kilovoltage to penetrate the part.

Experiment 5: Kv.P.–density relation

Procedure. Expose a series of four postero-anterior radiographs of the hand employing the following factors:

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	40
Time:	$^{4}/_{10}$ sec.
Ma.:	100
Kv.P.:	Variable factor
Development:	Automatic

Variable factors:

Exposure 1:	40 Kv.P.
Exposure 2:	50 Kv.P.
Exposure 3:	60 Kv.P.
Exposure 4:	70 Kv.P.

Comment. The overall density of the radiographs increases with the Kv.P. Successive increases in kilovoltage cause corresponding increases in density because of greater tissue penetration, since less radiation is absorbed by the tissues and more reaches the film.

Experiment 6: Testing film of two different manufacturers

Purpose. To find whether film A and film B of different manufacture may or may not be used interchangeably.

Procedure. A series of two radiographs of the skull in the lateral projections for each of the films should be made employing (1) low Kv.P. technique, and (2) higher Kv.P. technique.

Film:	Regular 10 x 12
Screens:	Medium 10 x 12
Grid:	8 to 1
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	100 or 150
Kv.P.:	Variable factor
Development:	Automatic

Variable factors:	*Kv.P.*	*Ma.S.*
Film A Exposure 1:	62	70
Film A Exposure 2:	85	15
Film B Exposure 3:	62	70
Film B Exposure 4:	85	15

Constant factor:
All films should be exposed employing the same cassette.

Comment. In order to show that films A and B may be used interchangeably, the contrast and density should remain the same for each set of radiographs.

Experiment 7: Kv.P.-Ma.S.–density relation

Purpose. To prove that satisfactory overall density can be made comparable by using Ma.S. to compensate for the density effect of changing kilovoltage, provided the radiation penetrates the structure.

Procedure 1. A series of four lateral radiographs of the skull should be made employing the following factors:

Film:	Regular 10 x 12
Screens:	Medium 10 x 12
Grid:	8 to 1
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	Variable factor
Kv.P.:	Variable factor
Development:	Automatic

Variable factors:	*Kv.P.*	*Ma.S.*
Exposure 1:	65	60
Exposure 2:	75	30
Exposure 3:	85	15
Exposure 4:	95	7.5

Procedure 2. Postero-anterior radiograph of the hand.

Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	Variable factor
Kv.P.:	Variable factor
Development:	Automatic

Variable factors:	*Kv.P.*	*Ma.S.*
Exposure 1:	50	70
Exposure 2:	60	30
Exposure 3:	70	20
Exposure 4:	80	10

Experiment 8: Effect of development and density

Purpose. To demonstrate that as development time increases, density increases.

Procedure. A series of 10 radiographs of the postero-anterior chest are made with the following factors:

Film:	Regular 14 x 17
Screen:	Medium 14 x 17
Grid:	None
Distance:	72-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	3.3
Time:	$^{1}/_{30}$ sec.
Ma.:	100
Kv.P.:	80
Development:	Variable factor
Measurement of patient:	22 cm.

Variable factors:

Exposure 1: Develop 1 min. at 68°
Exposure 2: Develop 2 min. at 68°
Exposure 3: Develop 3 min. at 68°
Exposure 4: Develop 4 min. at 68°
Exposure 5: Develop 5 min. at 68°
Exposure 6: Develop 6 min. at 68°
Exposure 7: Develop 7 min. at 68°
Exposure 8: Develop 8 min. at 68°
Exposure 9: Develop 9 min. at 68°
Exposure 10: Develop 10 min. at 68°
Manual processing

Experiment 9: Effect of temperature of developer on density

Purpose. To demonstrate the fact that as temperature increases, development time must be decreased to compensate for increased activity.

Procedure. Expose 4 postero-anterior radiographs of the chest with the following factors:

Film:	Regular 14 x 17
Screens:	Medium 14 x 17
Grid:	None
Distance:	72-in. FFD
Filter:	2-mm. aluminum

Cone:	To film
Ma.S.:	3.3
Time:	1/30 sec.
Ma.:	100
Kv.P.:	80
Development:	Variable factor
Measurement of patient:	22 cm.

Variable factors:

Exposure 1: Develop 8½ min. at 60°
Exposure 2: Develop 5 min. at 68°
Exposure 3: Develop 3½ min. at 75°
Exposure 4: Develop 2 min. at 80°
Manual processing

Experiment 10: Compensation of density by Ma.S. with increased kilovoltage

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Elbow	A.P.	7	40	36	100	2¾	275	0	Automatic	Regular	0
2				50			1¼	125				
3				60			.8	80				
4				70		50	.9	45				
5				80			.7	35				
6				90			.5	25				
7				100			.3	15				
8	Hand	P.A.		40		100	1½	150				
9				50		100	.4	40				
10				60		100	.2	20				
11				70		30	.4	12				
12				80		30	.25	7.5				
13				90		50	.1	5				
14				100		50	3/40	3.75				
15	Chest	P.A.	23	40	72	100	7/10	70	Average speed		Regular	0
16				50			2/10	20				

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
17				60			$^1/_{12}$	8.3				
18				70			$^1/_{20}$	5				
19				80			$^1/_{30}$	3.33				
20				90			$^1/_{20}$	2.5				
21				100		50	$^1/_{30}$	1.66				

Experiment 11: Increase in density with increase in kilovoltage

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Chest	P.A.	23	50	72	100	$^1/_{30}$	3.3	Average speed	Automatic	Regular	0
2				60								
3				70								
4				80								
5				90								
6				100								

Experiment 12: Use of inverse square law in compensating density with increase in distance

As distance increases, density is compensated for by inverse square law.

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Hand	P.A.	3	50	25	100	$^2/_{10}$	20	0	Automatic	Regular	0
2					30		$^3/_{10}$	30				
3					36		$^4/_{10}$	40				
4					40		$^5/_{10}$	50				
5					48		$^7/_{10}$	70				

Experiment 13: Decrease in density with increase in distance

As distance increases, density decreases, provided all other factors are constant.

No.	Region	Proj.	Cm.	Kv.	D.	Ma.	S.	Ma.S.	Scr.	Dev.	Film	P-B
1	Hand	P.A.	3	50	25	100	4/10	40	0	Automatic	Regular	0
2					30							
3					36							
4					40							
5					48							

Experiment 14: Effect of small changes in Kilovoltage on density

Small changes in kilovoltage on direct exposure cause no readily discernible change in density.

No.	Region	Proj.	Cm.	Kv.	D.	Ma.	S.	Ma.S.	Scr.	Dev.	Film	P-B
1	Hand	P.A.	3	45	36	100	4	40	0	Automatic	Regular	0
2				46								
3				47								
4				48								
5				49								
6				50								
7				51								
8				52								
9				53								
10				54								
11				55								
12	Chest	P.A.	23	75	72	100	1/20	3.3	Average speed		Regular	0
13				76								
14				77								
15				78								

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
16				79								
17				80								
18				81								
19				82								
20				83								
21				84								
22				85								

Experiment 15: Limited assistance of Ma.S. in removing secondary radiation fog

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Chest	P.A.	23	80	72	100	$^{1}/_{15}$	6.66	Average speed	Automatic	Regular	0
2				90			$^{1}/_{20}$	5.				
3				100			$^{1}/_{30}$	3.33				
4				80			$^{1}/_{30}$	3.33				
5				90			$^{1}/_{40}$	2.5				
6				100			$^{1}/_{60}$	1.66				

Experiment 16: Rule of thumb—halving or doubling Ma.S. to balance densities when Kv.P. is fixed

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Skull	Lat.	16	85	36	100	$^{1}/_{20}$	5	Average speed	Automatic	Regular	8-1
2							$^{1}/_{10}$	10				
3							9 imp.	7.5				
4	Skull	P.A.	18	80	36	100	$^{3}/_{10}$	30				
5						100	$^{3}/_{20}$	15				
6						50	$^{3}/_{20}$	7.5				
7				100		50	$^{2}/_{10}$	10				

Experiment 16, continued:

No.	Region	Proj.	Cm.	Kv.	D.	Ma.	S.	Ma.S.	Scr.	Dev.	Film	P-B
8							$^{1}/_{10}$	5				
9							$^{1}/_{20}$	2.5				
10	Shoulder	P.A.	14	60	36	50	$^{1}/_{20}$	2.5				0
11						50	$^{1}/_{10}$	5				0
12						50	$^{2}/_{10}$	10				0
13						100	$^{1}/_{30}$	3.3				0
14						100	$^{1}/_{24}$	4.125				0
15	1–7 Cervical vert.	Lat.	10.5	[illegible]5	72	100	$^{1}/_{20}$	5				0
16						50	$^{1}/_{20}$	2.5				0
17						50	$^{3}/_{40}$	3.75				0
18	Chest	R. obl.	31.5	85	72	100	$^{1}/_{10}$	10				0
19							$^{1}/_{20}$	5				
20	Leg	Lat.	8.5	60	36	25	$^{1}/_{30}$	.83				0
21							$^{1}/_{15}$	1.66				0
22	Chest	P.A.	23	80	72	100	$^{1}/_{15}$	6.6				0
23						100	$^{1}/_{30}$	3.3				0
24						100	$^{1}/_{60}$	1.66				0
25	Lumbar	A.P.	20	70	36	100	$^{1}/_{10}$	10				8-1
26							.2	20				8-1
27							.3	30				8-1
28	Use immobilization						.4	40				8-1

Experiment 17: Influence of a grid in removing secondary radiation fog

No.	Region	Proj.	Cm.	Kv.	D.	Ma.	S.	Ma.S.	Scr.	Dev.	Film	P-B
1	Chest	P.A.	25	80	72	100	$^{1}/_{24}$	4.16	Average speed	Automatic	Regular	0

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
2	Chest			100	72	100	$^1/_{24}$	4.16				Lysholm
3	Chest	Lat.	35	90	72	200	$^3/_{40}$	15				0
4	Chest			100	72	200	$^2/_{10}$	40				Lysholm

Experiment 18: Influence of cones and presence or absence P-B grid in elimination of secondary radiation fog

No.	*Region*	*Proj.*	*Cm.*	*Kv.*	*D.*	*Ma.*	*S.*	*Ma.S.*	*Scr.*	*Dev.*	*Film*	*P-B*
1	Skull	P.A.	19	70	36	100	$^6/_{10}$	60	Average speed	Automatic	Regular	8-1
2	Skull											
3	Skull											
4	Skull											
5	Skull											
6	Skull	P.A.	19	70	36	100	$^2/_{10}$	20				0
7	Skull											
8	Skull											
9	Skull											

Nos. 1 and 6 – no cone
Nos. 2 and 7 – 13-in. cone
Nos. 3 and 8 – 8-in. cone
Nos. 4 and 9 – 6-in. cone
Or collimation equivalent

Experiment 19: Wide exposure latitude

Procedure 1.

Absorber:	Step Wedge
Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid	None
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	10
Time:	$^1/_{10}$ sec.
Ma.:	100
Kv.P.:	Variable factor
Development:	Automatic

	Ma.S.	*Kv.P.*
Exposure 1:	10	60
Exposure 2:	10	70
Exposure 3:	10	80
Exposure 4:	10	90
Exposure 5:	10	100

Procedure 2.

Part:	AP elbow
Film:	Regular 8 x 10
Cardboard holder:	8 x 10
Grid:	None
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	100
Kv.P.:	60
Development:	Automatic

	Ma.S.	*Kv.P.*
Exposure 1:	50	60
Exposure 2:	70	60
Exposure 3:	90	60
Exposure 4:	120	60
Exposure 5:	140	60

Experiment 20: Narrow exposure latitude

Procedure 1.

Part:	PA chest
Film:	Regular 14 x 17
Screens:	Medium 14 x 17
Grid:	None
Distance:	72-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	100
Kv.P.:	60
Development:	Automatic

	Ma.S
Exposure 1:	2.5
Exposure 2:	5
Exposure 3:	10
Exposure 4:	15
Exposure 5:	20

Procedure 2.

Part:	Lateral skull
Film:	Regular 10 x 12
Screens:	Medium 10 x 12
Grid:	8 to 1
Distance:	36-in. FFD
Filter:	2-mm. aluminum
Cone:	To film
Ma.S.:	Variable factor
Time:	Variable factor
Ma.:	100
Kv.P.:	60
Development:	Automatic

	Ma.S.
Exposure 1:	50
Exposure 2:	100
Exposure 3:	150

Comment. When the kilovoltage is insufficient to penetrate the part, no practical amount of Ma.S. will compensate for density.

Chapter 6. **PRODUCING A RADIOGRAPH; TECHNICAL CONVERSION CHARTS**

The production of a radiograph involves *four* so-called primary factors. Three of these, *milliamperage, time* (Ma.S.) and *kilovoltage* (Kv.P.) are usually considered the factors controlled by the x-ray machine. The fourth factor is the *distance* from the focal spot of the x-ray tube to the film (focus-film distance).

The term milliampere-seconds (Ma.S.) is descriptive of the milliamperage or *amount* of current passing through the tube for a given period of *time.* The radiographic density of a film varies directly with the milliampere-seconds.

The kilovoltage, spoken of as kilovolts-peak or Kv.P., is the factor that controls *penetration* and *contrast.*

EXPOSURE

The word *exposure* has different radiographic meanings, depending upon the context. For example, "exposure" may be used to designate the radiographic conditions—kilovoltage, milliamperage, and time used for a certain technique. In somewhat different usage "exposure" may indicate only the milliamperage and time (Ma.S.) or source strength and time. Again, "exposure" is sometimes used to designate radiation exposure to the patient, in terms of roentgens. Exposure may refer to a measure, in absolute or relative units, of the amount of radiation reaching a certain area of the film. Exposure in the latter case means the amount of energy reaching a particular area of film and responsible for producing a particular density on the processed film. The word is thus used in the study of the sensitometric properties of x-ray films (see Chapter 1).

THE PRIMARY EXPOSURE FACTORS

1. For any radiographic problem, the "correct exposure" will require a precise combination of the four primary factors:

- *a.* Kilovoltage
- *b.* Milliamperage
- *c.* Exposure time
- *d.* Focus-film distance

Provided that no other factors in the radiographic problem are changed, the radiographic density may be altered to a predetermined degree by varying any one of the four primary factors.

2. Since milliamperage is so much a function of tube capacity, it is quite impractical to use it as a variable.

3. Time can be used as a variable with excellent results except where motion is a factor. In all moving parts there is a certain "optimum exposure time" beyond which motion becomes objectionable.

4. Kilovoltage affects both the quality and quantity of x-rays and hence can be used as a variable to compensate for differences in part thickness. This technique is practical only when the autotransformer design permits 1 or 2 kilovolt changes to be made.

5. Under average conditions, variations in part thickness will require compensations of 2 kilovolts per centimeter thickness (*with variable kilovoltage technique*).

6. Distance can be used as a variable, but is recommended only when control limitations and motion make kilovoltage or time variations impractical. Distance changes cause changes in image magnification with consequent image detail variations.

It is good technique to keep three factors constant and vary only the fourth to effect changes in radiographic density.

THE SECONDARY FACTORS

Intensifying screens

Until non-screen films were introduced, all x-ray film had an emulsion most sensitive to "blue light," the color of the fluorescence of calcium tungstate intensifying screens.

When intensifying screens are used, about 99 per cent of the total exposure is effected by "printing the visible image onto the x-ray film." Only about 1 per cent of the total exposure is caused by the x-rays striking the film.

When intensifying screens are used, the "scale of gradation" of the radiographic image is considerably shortened; hence the radiographic image has more contrast.

Cones

The amount of exposure compensation to be used for cones is governed by:

1. The proportionate decrease in "volume of part" radiated; this is governed by:
    a) Thickness of the part
    b) The size of the cone
    c) The focus-film distance
2. The structure of the part
3. The kilovoltage

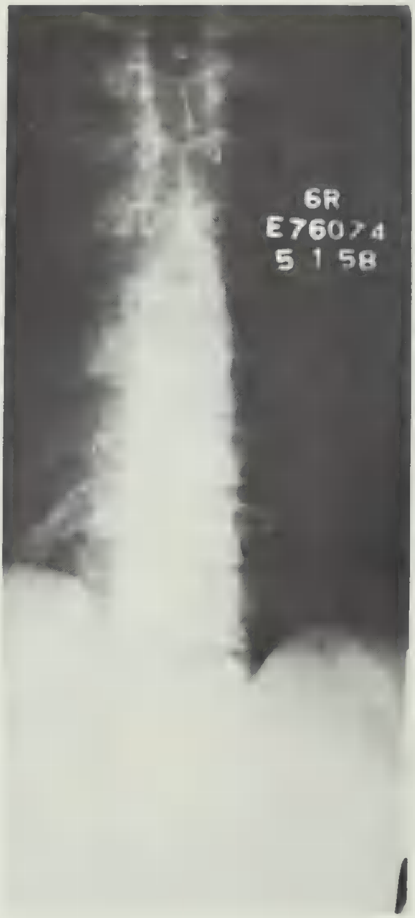
In general, when using a cone we have to add from 3 to 5 Kv.P. in order to compensate for loss in density due to the absorption of some of the primary radiation. By limiting the size of the x-ray beam by a cone, less tissue is irradiated and less secondary radiation is emitted to fog the film.

On occasion, distance and a cylinder cone may be used to an advantage. Figure 6.1 shows an anteroposterior radiograph of the thoracic-lumbar spine made on a 7 x 17 film. Since pathology was present, a spot film was requested in order to bring out more *detail* and *contrast*. The distance was decreased from 36 to 30 inches to overcome the absorption of the cylinder cone; all other factors remained the same. The resulting radiograph is shown in Figure 6.2.

The Potter-Bucky diaphragm

When a Potter-Bucky diaphragm is used, the exposure must be increased enough to compensate for:

Figure 6.1 A.P. radiograph of thoracic-lumbar spine on 7 × 17 film at a distance of 36 inches.



1. A reduction of about 85 per cent (depending on grid ratio) in the intensity of the *secondary radiation* reaching the film.

2. A slight reduction in the intensity of the *primary radiation* reaching the film, due to the filtration of the table top and the Bucky grid. Under average circumstances, a Bucky technique requires at least *3 times as much exposure as non-Bucky technique* or an increase in Kv.P – approximately 20 Kv.P. for an 8-1 grid. Stationary grids require slightly less exposure than that required for a Potter-Bucky diaphragm.

The smallest cone possible should be used for *every part.* A grid should be used for any part which is solid and not air-contained, or where there is edema or accumulation of fluid. In *general,* a grid should be considered for any part 12 centimeters and above except some small parts, sinuses, lateral mandible, etc.

In converting a non-grid technique to a grid technique, we must increase either the *Ma.S.* or the *kilovoltage* because of the absorption of the grid. Tables 6.1 and 6.2 may be used as guides in determining the conversion factor.

Figure 6.2. The same spine, a radiograph taken with a cone and spot film, distance decreased to 30 inches.

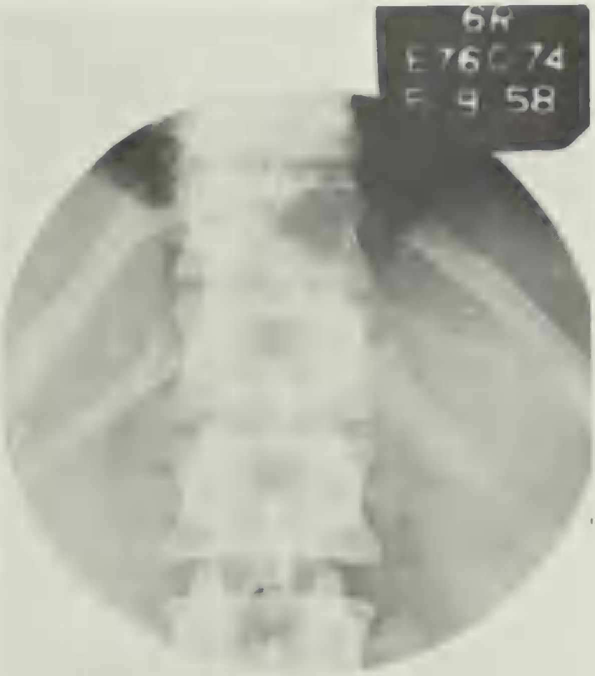


Table 6.1 GRID CONVERSION FACTORS IN Ma.S.

From No-Grid	*To*	*Ma.S.*
	5-1	Use 1½ times the Ma.S.
	6-1	Use 2 " " "
	8-1	Use 3 " " "
	12-1	Use 3½ " " "
	16-1	Use 4 " " "

Table 6.2 GRID CONVERSION FACTORS IN Kv.P.

From No-Grid	*To*	*Kv.P.*
	5-1	add 8 Kv.P.
	6-1	add 12 Kv.P.
	8-1	add 20 Kv.P.
	12-1	add 23 Kv.P.
	16-1	add 25 Kv.P.

Note: To change from an 8-to-1 grid to a 16-to-1 grid, add 6 Kv.P. or increase Ma.S. by 30 per cent.

Example: A non-grid technique for the A.P. knee calls for:

36-inch focus-film distance
100 Ma.
$\frac{1}{10}$ second
screens
60 Kv.P.

It is desired to increase the contrast scale by employing the 8-to-1 grid, we would then use: 36-inch focus-film distance

100 Ma.
$\frac{3}{10}$ second
screens
8-1 grid
60 Kv.P.

If we wanted to use Kv.P. for our conversion, we would use 80 Kv.P. and all other factors constant. See Figures 8.29 and 8.30.

MILLIAMPERAGE, TIME, DISTANCE, and KILOVOLTAGE

1. Milliamperage must necessarily depend upon the capacity of the x-ray unit (including the tube capacity) and the requirements of the focal-spot dimensions. High milliamperage imposes the requirements of relatively large focal-spot dimensions, which detract from the sharpness of detail.

2. Time of exposure should be reduced to a minimum to counteract the effects of motion. For all practical considerations, the time of exposure and the milliamperage are interchangable. The greater the milliamperage, the less will be the time of exposure required and vice versa.

3. Roughly, Kv.P. changes might be interpolated with respect to Ma.S. values as indicated in the following chart; however the chart should be used only for Kv.P. ranges from 60 Kv.P. to 80 Kv.P. Above 80 Kv.P. and below 60

Kv.P. the chart on Kilovoltage–Time Relation (Tables 6.4, 6.5, and 6.6) should be used.

To decrease kilovoltage by:

10 Kv.P. requires twice the amount of Ma.S.
13 Kv.P. requires three times the amount of Ma.S.
15 Kv.P. requires four times the amount of Ma.S.
20 Kv.P. requires five times the amount of Ma.S.

To increase kilovoltage by:

10 Kv.P. requires a reduction of one-half the Ma.S.
13 Kv.P. requires a reduction of one-third the Ma.S.
15 Kv.P. requires a reduction of one-fourth the Ma.S.
20 Kv.P. requires a reduction of one-fifth the Ma.S.

Kilovoltage–distance conversion

When a variation from an established distance is found necessary, the following chart will prove of value. *However, the use of the inverse square law will prove to be more accurate to maintain radiographic density and the contrast scale will remain about the same. The chart below should be used only when it is impossible to vary the Ma. and time values.*

Change in Distance		
From	*To*	*Change in Kv.P.*
36 inches	42 inches	add 5 Kv.P.
36 "	48 "	add 9 Kv.P.
36 "	54 "	add 11 Kv.P.
36 "	60 "	add 13 Kv.P.
36 "	72 "	add 16 Kv.P.
36 "	30 "	subtract 6 Kv.P.
72 "	60 "	subtract 5 Kv.P.
72 "	48 "	subtract 11 Kv.P.
72 "	36 "	subtract 20 Kv.P.

Kilovoltage–Ma.S. conversion factors

The charts in Table 6.3 can be used to increase the Ma.S. from two to ten times and/or decrease the Ma.S. from one half to one tenth.

Table 6.3 Kv.P. DECREASE TO BE MADE WHEN Ma.S. IS INCREASED

Initial Kv.P.	*2X*	*3X*	*4X*	*5X*	*10X*
40	4	6	7	9	13
45	5	8	9	11	15
50	6	10	11	13	18
55	7	12	13	15	21
60	8	13	15	17	23
65	9	14	17	19	25
70	10	15	19	20	27
75	11	16	20	22	29

Table 6.3, continued

Initial Kv.P.	*2X*	*3X*	*4X*	*5X*	*10X*
80	11	17	21	23	31
85	12	18	22	24	33
90	13	19	23	25	35
95	14	20	24	27	37
100	15	21	25	29	39
105	16	22	27	31	41
110	17	23	29	33	43
115	18	25	31	35	45
120	19	27	33	37	47
125	20	29	35	39	49
130	21	31	37	41	51

Figure 6.3 shows a radiograph of the skull made at 60 Kv.P. and 70 Ma.S. and Figure 6.4 shows the same patient's skull made at one half the Ma.S. and 68 Kv.P. These figures are taken from Table 6.4.

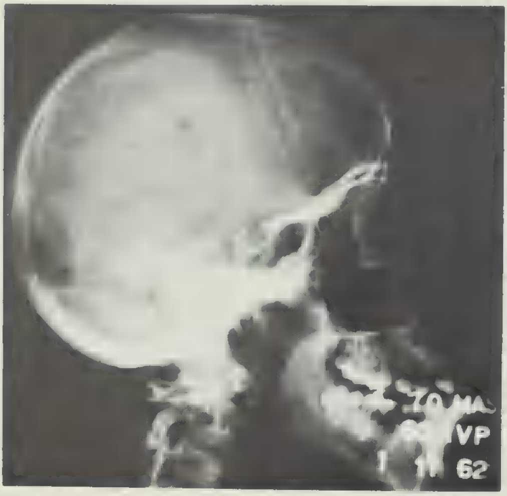


Figure 6.3 Radiograph of skull, at 70 Ma.S. and 60 Kv.P.

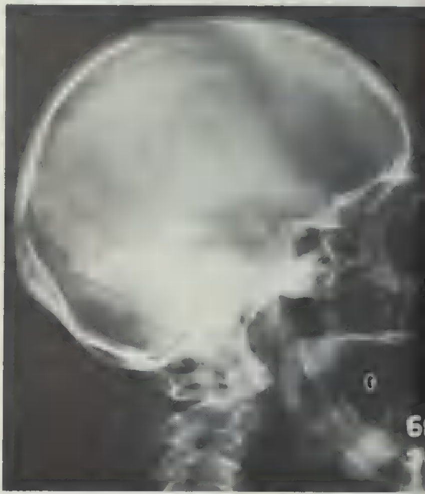


Figure 6.4. The skull of Figure 6.3, at 35 Ma 68 Kv.P.

Table 6.4 Kv.P. INCREASE TO BE MADE WHEN Ma.S. IS DECREASED

Initial Kv.P.	$^1/_2$	$^1/_3$	$^1/_4$	$^1/_5$	$^1/_{10}$
30	4	6	8	11	16
35	5	8	11	13	20
40	6	11	14	17	25
45	7	12	16	19	29
50	8	13	18	21	33
55	9	15	20	23	36
60	10	17	22	25	39
65	11	18	24	27	42

Initial Kv.P.	1/2	1/3	1/4	1/5	1/10
70	12	19	26	29	45
75	13	20	28	31	
80	14	21	30	33	
85	15	23	32		
90	16	25	34		
95	17	27			
100	18	30			

RELATION BETWEEN KILOVOLTAGE AND TIME

It is often necessary to *estimate* the kilovoltage approximately for a given change in exposure time, or what approximate change in exposure time is necessary to compensate for a desired change in kilovoltage. While it is not possible to give an exact rule for all cases, the table below provides estimates of the corrections that should be applied to kilovoltage or exposure time when either is changed. It must be kept in mind that an increase in kilovoltage with the exposure adjusted to maintain the same density will produce lower contrast in the radiograph; and, conversely, a decrease in kilovoltage will produce higher contrast.

6.5. Radiograph made at 85 Kv.P. and 30 Ma.S.

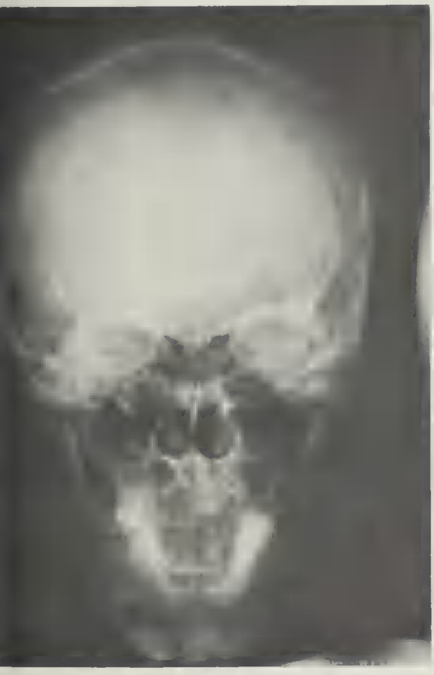
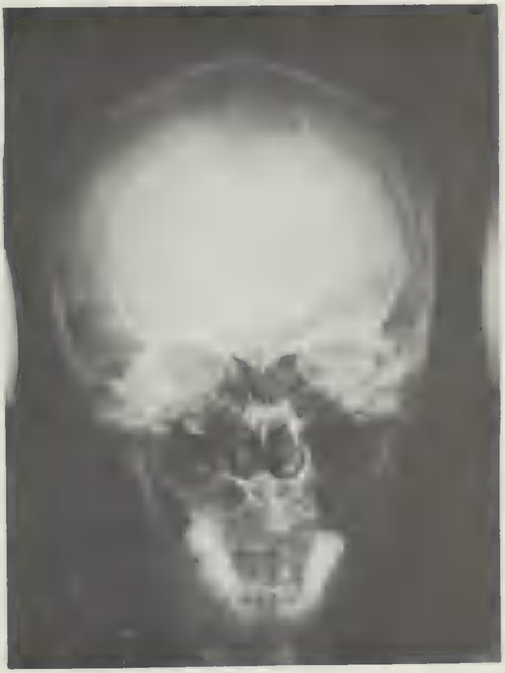


Figure 6.6. The skull of Figure 6.5, taken at 76 Kv.P. and 60 Ma.S. Increasing the exposure time 100 per cent demanded a 16 per cent decrease in Kv.P. See Tables 6.4, 6.5, and 6.6.



Example: Suppose that with intensifying screens a kilovoltage of 80 and an exposure time of 4 seconds have been employed, and it is desired to decrease the exposure time to 2 seconds. What kilovoltage would be required?

According to the table, the decrease in exposure time is 50 per cent, which necessitates a 20 per cent increase in kilovoltage:

20% of 80 Kv.P. = 16 Kv.P.

80 Kv.P. + 16 Kv.P. = 96 Kv.P.

Table 6.5

To decrease exposure time	*Increase kilovoltage*	
	With double screens	*Without screens*
25%	7%	15%
50%	20%	40%
75%	50%	100%

Table 6.6

To increase exposure time	*Decrease kilovoltage*	
	With double screens	*Without screens*
25%	5%	10%
50%	10%	18%
75%	13%	25%
100%	16%	30%

Example: Suppose that with intensifying screens a kilovoltage of 80 and an exposure time of 4 seconds have been employed, and it is desired to decrease the kilovoltage to 70. What exposure time would be required?

The decrease in kilovoltage is about 13 per cent, which necessitates a 75 per cent increase in exposure time.

75% of 4 sec. = 3 seconds

4 sec. + 3 sec. = 7 seconds

Kilovoltage–time relation (15 per cent rule). To reduce the exposure (Ma.S.) to one half *at any level* of kilovoltage, add 15% more kilovoltage.

Examples: We are employing a technique at 100 Ma.S. and 70 Kv.P. and we wish to reduce the time of exposure by one half our original.

$$\begin{array}{r} 70 \\ \underline{.15} \\ 350 \\ \underline{70} \\ 10.50 \end{array}$$

We would now add 10 or 11 Kv.P. and reduce the Ma.S. by one half.

We are employing a technique at 10 Ma.S. and 40 Kv.P. and wish to reduce the exposure time to 5 Ma.S.

$$\begin{array}{r} 40 \\ \underline{.15} \\ 200 \\ \underline{40} \\ 6.00 \end{array}$$

We would now use 46 Kv.P. and 5 Ma.S.

Ma.S.–DISTANCE RELATIONSHIP

The inverse square law* is one of the most important and most useful laws in *standardized* radiography because if factors that give a satisfactory radiograph at one distance are known and it is desired to increase or decrease the distance, the voltage may be kept constant (same contrast) and the new Ma.S. calculated by the following formula based on the inverse square law.

Example: A technique calls for 80 Kv.P. at a 72-inch focus-film distance and it is desired to decrease the distance to 36 inches. The old technique calls for 10 Ma.S. What would the new Ma.S. be at 36 inches?

$$\text{Ma.S.}_1:\text{Ma.S.}_2::D_1^2:D_2^2$$

$$10:x::72^2:36^2$$

$$5184x = 12960$$

$$x = 2.5$$

We then would use 2.5 Ma.S., 80 Kv.P. at a 36-inch focus-film distance.

Figure 6.7 shows a chest radiograph made at 72 inches. Using the above formula, the same subject was then radiographed at a 36-inch focus-film distance; the results are shown in Figure 6.8.

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*Also see pages 153–54.

ure 6.7. Radiograph of chest at 72 inches.

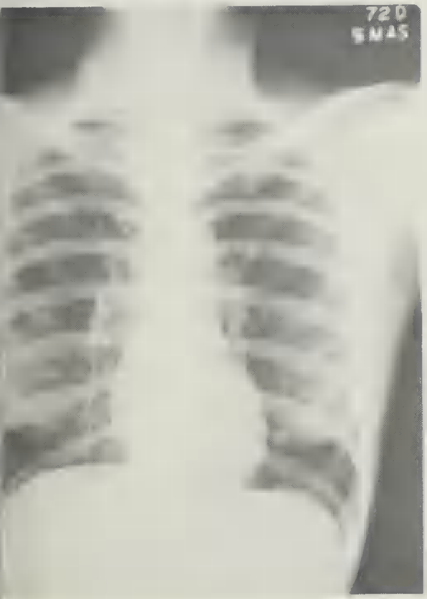
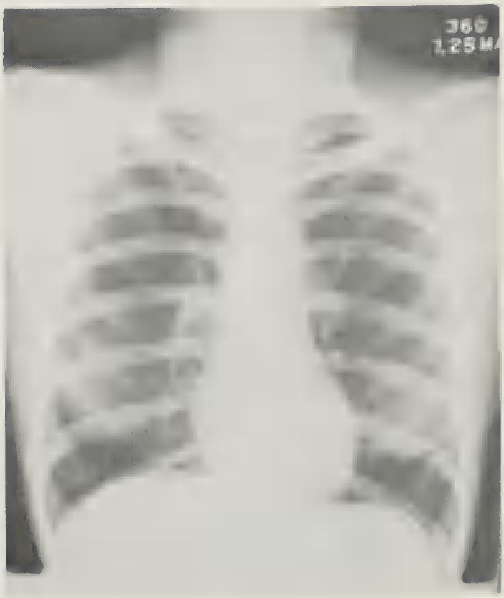


Figure 6.8 The chest of Figure 6.7, taken at 36 inches. A new milliamperage is determined by the inverse square law.



Ma.S.-distance formula (short method). Divide the original distance into the new distance. Square this answer. Multiply the squared answer by the original Ma.S. This will give the new Ma.S. to be used at the new distance.

Example:

Old distance 72 inches
Old Ma.S. 10
New distance 36 inches

$$\begin{array}{lll} \begin{array}{r} .5 \\ 72\overline{)36.0} \\ 36.0 \end{array} & \qquad \begin{array}{r} .5 \\ \underline{.5} \\ .25 \end{array} & \qquad \begin{array}{r} 10 \\ \underline{.25} \\ 2.50 \end{array} \end{array}$$

2.5 Ma.S. will be the new Ma.S. to be used at 36 inches.

Example:

Old distance 36 inches
Old Ma.S. 10
New distance 72 inches

$$\begin{array}{lll} \begin{array}{r} 2.0 \\ 36\overline{)72} \\ 72 \end{array} & \qquad \begin{array}{r} 2 \\ \underline{2} \\ 4 \end{array} & \qquad \begin{array}{r} 10 \\ \underline{4} \\ 40 \end{array} \end{array}$$

40 Ma.S. will be the new Ma.S. to be used at 72 inches.

THE FACTOR OF MOTION

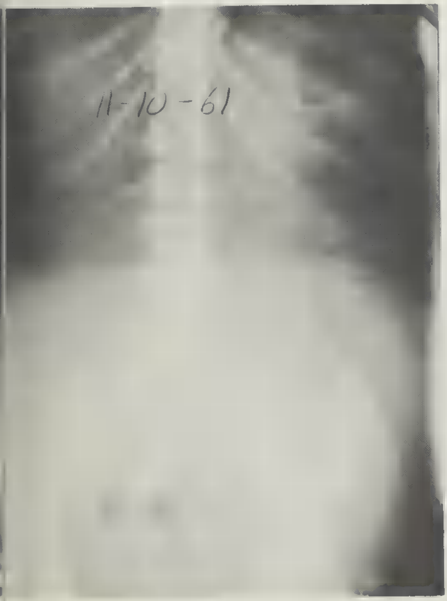
Certain types of work, such as radiography of infants and children, emergency radiography, bedside cases, and all technical procedure, if it is to be successfully utilized, must be based primarily upon the ability of the patient to hold still or the ability of the x-ray technologist to immobilize the patient successfully. It is of utmost importance that the x-ray technologist thoroughly understand the four prime factors in the production of a radiograph. If he is to acquire skill in his work, he must develop a keen sense of judging how long the patient or part will remain still, the ability to immobilize the part in such a way as to preclude the possibility of motion, and the ability to make the necessary changes in any of the four prime factors involved in order to attain a radiographic film of the highest quality. From the radiographic standpoint, motion may be classified into two groups: (*a*) physiological or involuntary, and (*b*) accidental or voluntary. Physiological motion is ordinarily considered as respiration, heart action, spasm, or tremor. Accidental motion refers to general body movement. Of these two forms of motion the latter may be more readily controlled. The former can be controlled by employing high milliamperages and short exposures. If high contrast films are desired, the *time of exposure* should be as long as possible with the *kilovoltages comparatively low.* Obviously, the employment of a low penetration or Kv.P. necessitates the use of an increased number of milliampere seconds.

In order that the highest quality results may be obtained it is necessary to know which of the previously mentioned causes of motion should be considered for each part. For example, radiography of the chest does not require that the time of exposure be based upon peristalsis, such as is found in the stomach and intestines. The three most common causes of motion in radiography of the chest are respiration, heart action, and accidental motion. Of the three, heart action ordinarily receives first consideration inasmuch as it is generally considered the most difficult to control. Were it not for the problem of motion due to the heart, obviously the time of exposure could be based either upon how long the individual could hold still, or the length of time the breath could be held. The normal cardiac cycle being approximately 70 beats per minute, one should try to utilize exposure factors of $^1/_{20}$ of a second or less.

If the region is the stomach, peristalsis and respiration, principally peristalsis, are the usual forms of motion necessary to control. Generally speaking, exposure values for this part range from $^1/_{30}$ of a second to $^1/_2$ second.

With certain types of injuries, muscle spasms, or tremors the possibility of successful immobilization is minimal. In such cases, the time of exposure may vary considerably.

Fixed or high kilovoltage techniques can be used to an exceptional advantage in the above-mentioned group since they make use of higher than usual kilovoltage and relatively short exposure.



e 6.9. This radiograph of the abdomen reveals aint outline of a fetal spine above the left iliac , but bone detail is somewhat blurred.

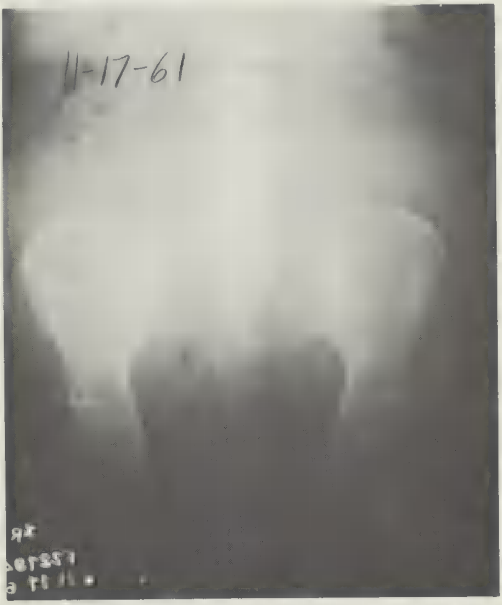


Figure 6.10. Another film was exposed a few days later, and a pregnancy of twins was confirmed. This and Figure 6.9 show what fetal motion can do to obscure fetal bone detail.

AGE CORRECTION

The following table used in correcting adult exposure to infant and children exposure factors is to be used from 40 to 80 Kv.P. *and does not apply to fixed kilovoltage technique.* It is not to be used for chest correction.

Table 6.7 CORRECTION FACTORS FOR AGE

Age	*Correction factor*
Birth to 3 months	.2
3 months to 2 years	.3
2 years to 5 years	.4
5 years to 7 years	.5
7 years to 12 years	.6

Courtesy: Clark R. Warren, R. T.

Procedure. Multiply the Ma.S. listed for adult by the correction factor and use kilovoltage as listed under centimeter thickness kilovoltage.

Example: The adult lateral skull calls for 100 Ma.S. and we wish to radiograph a two-year-old child. What will be the correct Ma.S.?

$$100 \times .3 = 30.0$$

Therefore, we should use 30 Ma.S., all other factors being constant. Employ the Kv.P. listed for the centimeter thickness.

GRID ABSORPTION

The approximate percentages of secondary radiation absorbed by grids of various ratios are: 5 to 1, 75 per cent; 6 to 1, 85 per cent; 8 to 1, 90 per cent; 12 to 1, 95 per cent.

A large part of the density produced on a film by an exposure made without a grid is due to secondary radiation, and because the grid itself absorbs some primary radiation, it is necessary to increase the exposure when a grid is used. The amount of increased Ma.S. or Kv.P. is dependent upon the *grid ratio* and the *kilovoltage* being used. See Tables 6.1 and 6.2 for conversion factors.

TISSUE ABSORPTION

The x-ray-absorption characteristics of tissues are unpredictable, for it is difficult to estimate their physiologic or pathologic state even with some measure of experience. It is not practical to try to establish these variables on a precise mathematical basis, but if the exposure system provides enough latitude for possible errors made in compensation, and the same body part is being considered in a given projection, a fairly close approximation may be attained. In the majority of cases, small deviations from the normal in tissue density or thickness can be ignored, but recognizable abnormal conditions of the body must be compensated for by adjustment of the variable exposure factor selected.

Producing a Radiograph

As the primary beam passes through a given body part, it is absorbed in accordance with the density and thickness of the tissues; the intensity of the primary radiation is thereby selectively diminished, and the remnant radiation is not uniform in intensity as it passes to the film. The greater the tissue absorption, the less intense is the remnant radiation that can affect the film in recording the image, and vice versa. In other words, the x-ray film is exposed by a pattern of the various intensities contained in the remnant beam, and upon development the radiograph exhibits different deposits of black metallic silver that are representative of these residual intensities. A relationship, therefore, exists between *tissue absorption* and *radiographic density*, as evidenced by the reduced intensity of any beam of remnant radiation.

All body parts present a proportional thickness of bone to soft tissue when evaluated for a given projection. This relationship does not vary to any appreciable extent from one person to another. A majority of patients exhibit tissue-thickness measurements for a given projection that are fairly constant within an average range (see page 171–72). An average range of these thicknesses can be established in which a basic exposure value can be applied. This range may be considered a constant for the bulk of exposures. Where the thicknesses are greater or smaller than the average, a rule of thumb may be applied for purposes of compensation—either double or halve the exposure, respectively.

DECIMAL EQUIVALENTS OF FRACTIONAL EXPOSURES

In computing milliampere-seconds values, it is often more convenient to use the decimal equivalent of the exposure time fraction. Table 6.8 below lists decimal equivalents of various exposure fractions. The numerators of fractions are listed horizontally at the top of the table; the denominators are listed vertically. The square common to both contains the decimal equivalents.

Example: To determine the decimal equivalent of the fraction $^3/_5$, find the number 3 in the horizontal row at the top of the table. Then find 5 in the left-hand vertical column; the square common to both columns will show .6. The milliamperage may be multiplied by this decimal to obtain the milliampere-seconds value.

If we were using 100 Ma. for $^3/_5$ of a second, we would now have 100 × .6, or 60 Ma.S.

RELATION BETWEEN TIME AND DISTANCE

Rule. The exposure time (T) required for a given exposure is directly proportional to the square of the anode-film distance (D).

Example: Suppose that an exposure time of 10 seconds (T_1) and an anode-film distance of 30 inches have been employed, and it is desired to decrease the anode-film distance to 24 inches (D_2); what exposure time (T_2) would be required?

$T_1:T_2::D_1^2:D_2^2$

$10:x::30^2:24^2$

$900x = 5760$

$x = 6.4$ seconds

Example of this problem would apply to radiography of the temporomandibular articulation, where use of close anode-film distance is desired.

Table 6.8 DECIMAL EQUIVALENTS OF FRACTIONAL EXPOSURES

	Numerators												
Denominators	1	2	3	4	5	6	7	8	9	10	11	12	Denominators
2	0.5	1.	1.5	2.	2.5	3.	3.5	4.	4.5	5.	5.5	6.	2
3	.333	.666	1.	1.33	1.666	2.	2.33	2.66	3.	3.33	3.66	4.	3
4	.25	.5	.75	1.	1.25	1.5	1.75	2.	2.25	2.5	2.75	3.	4
5	.2	.4	.6	.8	1.	1.2	1.4	1.6	1.8	2.	2.2	2.4	5
6	.167	.333	.5	.667	.835	1.	1.167	1.333	1.5	1.667	1.833	2.	6
7	.143	.286	.429	.572	.715	.858	1.	1.143	1.286	1.429	1.57	1.7	7
8	.125	.25	.375	.5	.625	.75	.875	1.	1.125	1.25	1.375	1.5	8
9	.111	.222	.333	.444	.555	.666	.777	.888	1.	1.111	1.222	1.333	9
10	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.	1.1	1.2	10
11	.09	.18	.27	.363	.455	.545	.636	.727	.818	.090	1.	1.09	11
12	.083	.167	.25	.333	.415	.5	.583	.667	.75	.833	.917	1.	12
15	.067	.134	.2	.267	.333	.4	.467	.533	.6	.667	.733	.8	15
20	.05	.1	.15	.2	.25	.3	.35	.4	.45	.5	.55	.6	20
24	.042	.083	.125	.167	.208	.25	.292	.333	.375	.416	.458	.5	24
30	.033	.067	.1	.133	.167	.2	.233	.267	.3	.333	.367	.4	30
40	.025	.05	.075	.1	.125	.15	.175	.2	.225	.25	.275	.3	40
60	.017	.033	.05	.067	.083	.1	.117	.133	.15	.167	.183	.2	60
120	.008	.017	.025	.033	.042	.05	.058	.067	.075	.083	.092	.1	120

Example: Suppose that an exposure time of two seconds (T_1) and an anode-film distance of 72 inches (D_1) have been employed, and it is desired to decrease the exposure time to $^1/_4$ seconds (T_2); what distance (D_2) would be required?

$$T_1 : T_2 :: D_1^2 : D_2^2$$

$$2 : {}^1/_4 :: 72^2 : x^2$$

$$2x^2 = 1296$$

$$x = 25.5 \text{ inches}$$

RELATION BETWEEN MILLIAMPERAGE, TIME, AND DISTANCE

Rule. Since the milliamperage (M) and the time (T) required for a given exposure are both directly proportional to the square of the anode-film distance (D), the product of the two, milliampere seconds (Ma.S.) or (MT), is also directly proportional to the square of the anode-film distance (D).

Example: Suppose that 60 Ma.S. (MT_1) and an anode-film distance of 36 inches (D_1) have been employed, and it is desired to increase the anode-film distance to 72 inches (D_2); what milliampere-second factor (MT_2) would be required?

$$MT_1 : MT_2 :: D_1^2 : D_2^2$$

$$60 : x :: 36^2 : 72^2$$

$$1296x = 311040$$

$$x = 240 \text{ milliampere seconds}$$

An easy method for calculating the change in milliampere seconds (Ma.S.) is based on the principle that the *squares* of numbers bear constant mathematical relation to each other. In the above example, the square of the number representing the longer anode-film distance 72^2 (5184), is 4 times the square of the number representing the shorter anode-film distance, 36^2 (1296). Therefore, if the number representing the proper Ma.S. factor at the 36-inch anode-film distance, 60, is multiplied by 4, the proper milliamperage time for the 72-inch distance will be found to be 240 Ma.S. Conversely, 36^2 (1296) is one-fourth (.25) of 72^2 (5184); so, if the number representing the proper Ma.S. factor at 72 inches, 240, is multiplied by .25, the proper milliamperage time for the 36-inch distance will be found to be 60 Ma.S.

The interrelation of all anode-film distances may be similarly expressed by means of a conversion factor. Any change in milliamperage seconds necessitated because of a change in the anode-film distance may then be calculated by multiplying by the proper factor, the initial milliamperage-seconds value. Table 6.14 below lists the factors that apply for anode-film distances commonly employed in radiography.

RELATION BETWEEN MILLIAMPERAGE AND DISTANCE

Rule. The milliamperage (M) required for a given exposure is directly proportional to the square of the anode-film distance (D).

Example: Suppose that 50 Ma. (M_1) and an anode-film distance of 36 inches (D_1) have been employed and it is desired to increase the distance to 72 inches (D_2) in order to obtain sharper detail; what Ma. would be required?

$$M_1 : M_2 :: D_1^2 : D_2^2$$

$$50 : x :: 36^2 : 72^2$$

$$1296x = 259{,}200$$

$$x = 200 \text{ milliamperes}$$

Example: Suppose that 100 milliamperes (M_1) and an anode-film distance of 72 inches (D_1) have been employed with a large focal spot and it is desired to change to a smaller focus tube designed to operate at considerably lower milliamperage. The milliampere factor selected is 20 (M_2). What distance (D_2) would be required?

$$M_1 : M_2 :: D_1^2 : D_2^2$$

$$100 : 20 :: 72^2 : x^2$$

$$100x^2 = 103{,}680$$

$$x^2 = \frac{103{,}680}{100}$$

$$x^2 = 1036.8$$

$$x = 32.2 \text{ inches}$$

Example: Suppose that we are using a double-focus rotating-anode tube having 1 millimeter and 2 millimeter focal spots. 500 milliamperes (M_1) and an anode-film distance of 72 inches (D_1) have been employed for the 2 millimeter focal spot. It is desired to employ the 1 millimeter focal spot with a milliamperage factor of 175 (M_2). What anode-film distance (D_2) would be required?

$$M_1 : M_2 :: D_1^2 : D_2^2$$

$$500 : 175 :: 72^2 : x^2$$

$$500x^2 = 907{,}200$$

$$x^2 = \frac{907{,}200}{500}$$

$$x^2 = 1814.4$$

$$x = 42.6 \text{ inches}$$

RELATION BETWEEN MILLIAMPERAGE AND TIME

Rule. The milliamperage (M) required for a given exposure is inversely proportional to the time (T). When radiographing children and nervous patients, it is often necessary to employ high Ma. in order to obtain the advantages of very short exposure.

Example: Suppose that 30 milliamperes (M_1) and an exposure time of $\frac{1}{2}$ second (T_1) have been employed, and it is desired to decrease the exposure time to $\frac{1}{20}$ second (T_2); what milliamperage would be required?

$$M_1 : M_2 :: T_2 : T_1$$

$$30 : x :: \tfrac{1}{20} : \tfrac{1}{2}$$

$$\tfrac{1}{20}\, x = 15$$

$$\frac{x}{20} = \frac{15}{1}$$

$$x = 15 \times 20$$

$$x = 300 \text{ Ma.}$$

Example: Suppose that 30 Ma. (M_1) and an exposure time of 2 seconds (T_1) have been employed, and it is desired to increase the milliamperage to 60 (M_2); what exposure time (T_2) would be required?

$$M_1 : M_2 :: T_2 T_1$$

$$30 : 60 :: x : 2$$

$$60x = 60$$

$$x = \text{one second}$$

MAINTAINING FOCUS-FILM DISTANCE AFTER TUBE IS ANGLED

Table 6.9 determines accurately where to place a tilted x-ray tube so that when the central ray is correct with the regional landmark, the anatomical region will be projected in the center of the film and the desired or original focus-film distance will be maintained.

If an x-ray tube is angled other than 90° and the tube is left in its original position, the resultant radiograph will be *underexposed*.

Table 6.9 DATA FOR TUBE ANGLES USED IN RADIOGRAPHY

	Z 25″			*Z 30″*			*Z 36″*			*Z 40″*	
A	*x*	*y*	*A*	*x*	*y*	*A*	*x*	*y*	*A*	*x*	*y*
5°	2.15	24.8	5°	2.6	29.8	5°	2.8	35.8	5°	3.5	39.8
10°	4.3	24.5	10°	5.2	29.6	10°	6.2	35.5	10°	6.9	39.4
13°	5.6	24.25	13°	6.75	29.25	13°	8.0	35.0	13°	9.0	39.0
15°	6.5	24.125	15°	7.75	29.0	15°	9.3	34.8	15°	10.4	38.6
17°	7.3	24.0	17°	8.6	28.6	17°	10.3	34.4	17°	11.6	38.2
20°	8.5	23.5	20°	10.25	28.2	20°	12.6	33.8	20°	13.75	37.6
23°	9.75	23.0	23°	11.7	27.6	23°	14.0	33.0	23°	15.6	36.8
25°	10.5	22.6	25°	12.7	27.2	25°	15.4	32.6	25°	16.8	36.0
30°	12.5	21.5	30°	15.0	26.0	30°	18.0	31.2	30°	20.0	34.6
35°	14.6	20.5	35°	17.25	24.6	35°	20.6	29.5	35°	23.0	32.8
40°	16.0	19.2	40°	19.3	23.0	40°	23.2	27.6	40°	25.75	30.25
45°	17.7	17.7	45°	21.25	21.25	45°	25.4	25.4	45°	28.25	28.25

Z = Focus-film distance *A* = Tube angle *x* = Tube shift *y* = New vertical distance

Courtesy: Ralph Tarrant, R. T.

Example: A. P. view of the petrous bone, at a 36-inch focus-film distance; the tube has to be tilted 35 degrees. What distance should you use at the 35-degree tilt? According to the chart on the 36-inch distance column we have:

Z – 36-inch distance
A – 35-degree tilt
X – tube shift to have central ray to center of film
Y – new vertical distance, which will be 29.5 inches

Table 6.10 MILLIAMPERE-SECONDS–F.F. DISTANCE CONVERSION

Original Ma.S.	*Original distance*	*New distance*	*New Ma.S. to provide equal density*
5	72 inches	36 inches	1.3
5	72	48	2.2
5	72	60	3.3
5	36	72	20
5	36	60	15
5	36	48	9
5	36	40	6.5
5	36	30	3.3
10	72	60	7
10	72	48	4.5
10	72	40	3

Table 6.10, continued

Original Ma.S.	*Original distance*	*New distance*	*New Ma.S. to provide equal density*
10	72	36	2.5
10	36	40	12
10	36	48	17
10	36	60	28
10	36	72	40
50	30	36	70
50	30	40	90
50	30	48	130
50	30	60	200
50	30	72	300
50	36	40	60
50	36	48	90
50	36	60	140
50	36	72	200
50	48	60	80
50	48	72	110
50	72	36	12
50	48	36	28
50	48	30	19
100	30	36	150
100	30	40	170
100	30	60	330
100	36	40	120
100	36	60	240
100	72	36	25

Example: Suppose the focus-film distance is 36 inches and the Ma.S. is 10. It is desired to increase the distance to 72 inches. What Ma.S. value will produce an equal radiographic density?

Find 10 Ma.S. in the left-hand column which corresponds to 36 inches in the second column and the new distance in the third column.

The correct Ma.S. will be found in column four. The correct Ma.S. in this example is 40.

Table 6.11 IMPULSE–TIME–MILLIAMPERE-SECONDS

Impulses	*Time (seconds)*	*Milliampere seconds*											
2	1/60	.16	.25	.33	.41	.5	.83	1.66	2.5	3.33	5.	6.66	8.33
3	1/40	.25	.37	.5	.62	.75	1.25	2.5	3.75	5.	7.5	10.	12.5
4	1/30	.33	.5	.66	.83	1.	1.66	3.33	5.	6.66	10.5	13.33	16.66
5	1/24	.41	.62	.83	1.04	1.25	2.08	4.12	6.25	8.33	12.5	16.66	20.83
6	1/20	.5	.75	1.	1.25	1.5	2.5	5.	7.5	10.	15.	20.	25.
7		.58	.87	1.16	1.56	1.75	2.91	5.83	8.75	11.66	17.5	23.33	29.16
8	1/15	.66	1.	1.33	1.66	2.	3.33	6.66	10.	13.33	20.	26.66	33.33
9	3/40	.75	1.12	1.5	1.87	2.25	3.75	7.5	11.25	15.	22.5	30.	37.5
10	1/2	.83	1.25	1.66	2.08	2.5	4.16	8.33	12.5	16.66	25.	33.33	41.66
11		.91	1.37	1.83	2.27	2.75	4.58	9.16	13.75	18.33	27.5	36.66	45.83
12	1/10	1.	1.5	2.	2.5	3.	5.	10.	15.	20.	30.	40.	50.
13		1.08	1.62	2.16	2.77	3.25	5.41	10.83	16.25	21.66	32.5	43.33	54.16
14		1.16	1.75	2.33	2.91	3.5	5.83	11.66	17.5	23.33	35.	46.66	58.33
15		1.25	1.87	2.5	3.12	3.75	6.25	12.5	18.75	25.	37.5	50.	62.5

Impulses	Time (seconds)	Milliampere seconds											
16	2/15	1.33	2.	2.66	3.33	4.	6.66	13.33	20.	26.66	40.	53.33	66.66
17		1.41	2.12	2.83	3.54	4.25	7.08	14.16	12.25	28.33	42.5	56.66	70.83
18	3/20	1.5	2.25	3.	3.75	4.5	7.5	15.	22.5	30.	45.	60.	75.
19		1.58	2.37	3.16	3.95	4.75	7.91	15.83	23.75	31.66	47.5	63.33	79.16
20		1.66	2.5	3.33	4.16	5.	8.33	16.66	25.	33.33	50.	66.66	83.33
21		1.75	2.62	3.5	4.37	5.25	8.75	17.5	26.25	35.	52.2	70.	87.5
22		1.83	2.75	3.66	4.58	5.5	9.16	18.33	27.5	36.66	55.	73.33	91.66
23		1.91	2.87	3.83	4.79	5.75	9.58	19.16	28.75	38.33	57.5	76.66	95.83
24	1/5	2.	3.	4.	5.	6.	10.	20.	30.	40.	60.	80.	100.
25		2.08	3.12	4.16	5.20	6.25	10.41	20.83	33.26	41.66	62.5	83.33	104.16
26		2.16	3.25	4.33	5.41	6.5	10.83	21.66	32.5	43.33	65.	86.66	108.33
27		2.25	3.37	4.5	5.62	6.75	11.25	22.5	33.75	45.	67.5	90.	112.5
28		2.33	3.5	4.66	5.83	7.	11.66	23.33	35.	46.66	70.	93.33	116.66
29		2.41	3.62	4.83	6.04	7.25	12.08	24.16	36.25	48.33	72.5	96.66	120.83
30	1/4	2.5	3.75	5.	6.25	7.5	12.5	25.	37.5	50.	75.	100.	125.
Milliamperes		10	15	20	25	30	50	100	150	200	300	400	500

Table 6.12 MILLIAMPERE TIME COMPUTATIONS

Impulses	*Time*	*25 Ma.*	*50 Ma.*	*100 Ma.*	*150 Ma.*	*200 Ma.*	*300 Ma.*
1	1/120	.2	.5	.8	1.3	1.6	2.6
2	1/60	.4	.8	1.6	2.5	3.3	5
3	1/40	.6	1.2	2.5	3.7	5	7.5
4	1/30	.83	1.6	3.3	5	6.6	10
5	1/24	1	2.1	4.2	6.2	8.3	12.5
6	1/20	1.2	2.5	5	7.5	10	15
8	1/15	1.6	3.3	6.6	10	13.3	20
10	1/12	2.1	4.2	8.3	12.5	16.6	25
12	1/10	2.5	5	10	15	20	30
15	1/8	3.1	6.2	12.5	18.7	25	37.5
16	2/15	3.3	6.6	13.3	20	26.6	40
18	3/20	3.7	7.5	15	22.5	30	45
20	1/6	4.2	8.3	16.6	25	33.3	50
24	1/5	5	10	20	30	40	60
30	1/4	6.2	12.5	25	37.5	50	75
32	4/15	6.6	13.3	26.6	40	53.3	80
36	3/10	7.5	15	30	45	60	90
	4/10	10	20	40	60	80	120
	5/10	12.5	25	50	75	100	150
	6/10	15	30	60	90	120	180
	7/10	17.5	35	70	105	140	210
	3/4	18.7	37.5	75	112.5	150	225
	8/10	20	40	80	120	160	240
	9/10	22.5	45	90	135	180	270

Table 6.12, continued

Impulses	*Time*	*25 Ma.*	*50 Ma.*	*100 Ma.*	*150 Ma.*	*200 Ma.*	*300 Ma.*
	1	25	50	100	150	200	300
	1¼	31.2	62.5	125	187.5	250	375
	1½	37.5	75	150	225	300	450
	1¾	43.7	87.5	175	262.5	350	525
	2	50	100	200	300	400	600
	2¼	56.2	112.5	225			
	2½	62.5	125	250			
	2¾	68.7	137.5	275			
	3	75	150	300			
	3¼	81.2	162.5	325			
	3½	87.5	175	350			
	3¾	93.7	187.5	375			
	4	100	200	400			

400 Ma.	*500 Ma.*	*600 Ma.*	*700 Ma.*	*800 Ma.*	*1000 Ma.*	*1200 Ma.*
3.3	4.2	5	5.8	6.6	8	10
6.6	8.3	10	11.6	13.3	16	20
10	12.5	15	17.5	20	25	30
13.3	16.6	20	23.3	26.6	33	40
16.6	21	25	29	33.3	41	50
20	25	30	35	40	50	60
26.6	33.3	40	46.6	53.3	66	80
33.3	41.6	50	58.3	66.6	83	100
40	50	60	70	80	100	120
50	62.5	75	87.5	100	125	150
53.3	66.6	80	93.3	106.6	133	160
60	75	90	105	120	150	180
66.7	83.3	100	116.6	133	166	200
80	100	120	140	160	200	240
100	125					
106.6	133.3					
120	150					

CONVERSION OF MILLIAMPERE SECONDS AT VARIOUS MILLIAMPERAGES

Table 6.13 shows Ma., Time, and Milliampere Seconds.

Example: What time is used at 50 Ma. to obtain 2.5 Ma.S.? Locate 50 Ma. in the left hand column and 2.5 at the top Ma.S column, read down, find 1/20 second opposite 50 Ma.

Table 6.13 CONVERSION OF Ma.S. AT VARIOUS MILLIAMPERAGES

Milliampere seconds—across

Time of exposure—read down

Ma. down	1	2	2.5	3	4	5	6	8	10	12	14	15	20	25	30	40	50	60	75	100	150	200	300	500
5	2/10	4/10	1/2	6/10	8/10	....	....	....	2	....	....	3	4	5	6	8	10	12	....	....	....	....	....	....
10	1/10	2/10	1/4	3/10	4/10	1/2	6/10	8/10	1	....	....	....	2	....	3	4	2 1/2	6	....	10	....	20	....	....
15	....	....	....	2/10	....	....	4/10	....	7/10	8/10	9/10	....	....	....	2	....	....	4	5	....	....	....	....	....
20	1/20	1/10	1/8	3/20	2/10	1/4	3/10	4/10	1/2	6/10	7/10	3/4	1	....	1 1/2	2	2 1/2	3	....	5	....	10	....	....
25	....	....	1/10	1/8	....	2/10	....	....	....	....	....	6/10	....	....	....	....	2	....	....	4	6	8	....	....
30	1/30	1/15	....	1/10	....	....	2/10	....	....	4/10	....	1/2	....	....	....	....	....	3	....	....	5	....	10	....
40	1/40	1/20	....	....	1/10	1/8	3/20	2/10	1/4	3/10	....	....	1/2	6/10	3/4	1	....	1 1/2	....	2 1/2	....	....	....	....
50	....	1/24	1/20	....	....	1/10	1/8	....	2/10	1/4	1/3	3/10	4/10	1/2	6/10	8/10	....	....	....	2	3	4	6	....
60	1/60	....	1/24	1/20	1/15	....	1/10	....	....	2/10	....	1/4	....	4/10	1/2	....	....	1	....	....	....	....	5	....
70	....	....	....	....	....	....	....	....	....	....	2/10	....	....	....	....	7/10	....	9/10	....	....	....	....	....	....
75	....	....	1/30	1/24	....	1/15	....	....	....	....	....	2/10	....	....	4/10	....	....	8/10	1	....	2	....	....	....
80	....	1/40	....	....	1/20	....	....	1/10	1/8	3/20	....	....	1/4	3/10	....	1/2	....	3/4	....	1 1/4	....	....	....	....
90	....	....	....	1/30	....	....	1/15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
100	....	....	1/40	....	1/24	1/20	....	1/12	1/10	1/8	1/7	3/20	2/10	1/4	3/10	4/10	1/2	6/10	3/4	1	1 1/2	2	3	5
150	....	....	1/60	....	....	1/30	1/24	....	1/15	....	1/15	1/10	....	....	2/10	....	....	4/10	1/2	....	1	....	2	....
200	....	....	....	....	....	1/40	....	1/24	1/20	....	....	....	1/10	1/8	3/20	2/10	1/4	3/10	....	1/2	3/4	1	....	....
250	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
300	....	....	....	....	....	1/60	....	....	1/30	1/24	....	1/20	1/15	....	1/10	....	....	2/10	1/4	1/3	1/2	....	1	....
400	....	....	....	....	....	....	....	....	1/40	....	....	....	....	....	....	1/10	1/8	3/20	....	1/4	....	1/2	3/4	....
500	....	....	....	....	....	....	....	....	....	1/40	....	....	1/20	1/20	....	....	1/10	1/8	3/20	1/5	3/10	....	6/10	1

Example: What time is used at 50 Ma. to obtain 2.5 Ma.S.? Locate 50 Ma. in the left hand column and 2.5 at the top Ma.S. column, read down, find 1/20 second opposite 50 Ma.

CORRECTION FACTORS FOR CHANGE IN FOCUS-FILM DISTANCE

Table 6.14 lists the factors that apply for focus-film (anode-film) distances commonly employed in radiography. The initial focus-film distance is located in the left-hand vertical column and the desired distance is located in the horizontal column at the bottom of the chart. The required Ma.S. conversion factor will be found in the entry common to both columns.

Table 6.14 CORRECTION FACTORS FOR FOCUS-FILM DISTANCE

Initial focus-film distance	*Ma.S. conversion factors*							
20 in.	1.00–	1.56–	2.25–	3.22–	4.00–	5.76–	9.00–	12.96
25 in.	.64–	1.00 –	1.44–	2.07–	2.56–	3.68–	5.76–	8.29
30 in.	.44–	.69–	1.00–	1.44–	1.77–	2.56–	4.00–	5.76
36 in.	.31–	.48–	.69–	1.00–	1.23–	1.77–	2.77–	4.00
40 in.	.25–	.39–	.56–	.81–	1.00–	1.44–	2.25–	3.24
48 in.	.17–	.27–	.39–	.59–	.69–	1.00–	1.56–	2.25
60 in.	.11–	.17–	.25–	.36–	.44–	.64–	1.00–	1.44
72 in.	.08–	.12–	.17–	.25–	.31–	.44–	.69–	1.00
Desired focus-film distance	20 in.	25 in.	30 in.	36 in.	40 in.	48 in.	60 in.	72 in.

Example: We are employing a technique at a 30-inch distance, and it is desired to decrease the distortion by going to 48 inches. What would we multiply our *original* Ma.S. by? Find 30-inch distance in the left-hand vertical column and 48-inch distance in the horizontal column at the bottom of the chart. The required conversion factor will be 2.56. If we were using 10 Ma.S. at 30 inches, we would multiply 10 by 2.56 to arrive at the correct Ma.S. at 48 inches. The correct Ma.S. would be 25.60 or 26 Ma.S. In this case we would no doubt use 25 Ma.S.

See Figures 6.7 and 6.8, radiographs of the chest at 72 and 36 inches.

CAST RADIOGRAPHY

When using optimum kilovoltage techniques, measure the part and add 10 Kv.P. or 2 x Ma.S.

For lower voltage techniques, measure the part and add 10 Kv.P. for a dry cast and 15 Kv.P. for a wet cast. It is better to alter Kv.P. than Ma.S. If, however, one prefers to use Ma.S., the correction factor would be to double the Ma.S.

ADAPTING EXPOSURE TECHNIQUE FROM ONE HOSPITAL TO ANOTHER

From any given technique chart one may adapt the exposure factors to apply to any other machine.

Procedure. Choose a part from any group of parts of similar density. Make three exposures and divide the Ma.S. from the chart being adapted into the Ma.S. producing the most desired density with the new chart. The result obtained serves as the correction factor for all parts of similar density.

Example: A technique from Hospital A for the A.P. skull calls for 85 Kv.P., 20 Ma.S., 36-inch focus–film distance, medium screens, 8-to-1 grid. It is desired to adapt this technique to Hospital B.

At Hospital B we make three exposures of the skull, employing all factors as used at Hospital A, except the *milliampere-seconds*. Use the following three exposures:

1. Below the original Ma.S.
2. Equal to the original Ma.S.
3. Above the original Ma.S.

We would use 15, 20, 25 Ma.S. Process all three films at the same time for 5 minutes at 68°.

We now find that the film exposed at 25 Ma.S. produces the desired density, thus:

$$
\begin{array}{r|l}
 & 1.25 \\ \hline
20 & 25.0 \\
 & \underline{20} \\
 & 50 \\
 & \underline{40} \\
 & 10/20
\end{array}
$$

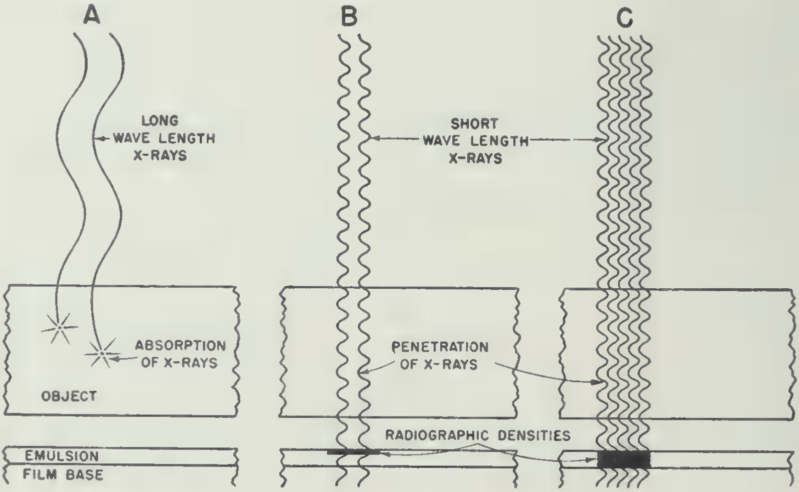
We would now multiply all Ma.S. values in the skull group by 1.25. All other factors remain constant.

Chapter 7. ESSENTIALS OF THE RADIOGRAPH AND IMAGE FORMATION

Every radiologic technologist should have a satisfactory working knowledge of *density, contrast, detail* and *distortion*. He should be able to understand and define the meaning of each; to differentiate each from the other in the finished radiograph; to understand and control each of the various subfactors that enter into the control of each of the main factors; to be able to arrange the four main factors and their subfactors so that any desired results may be obtained. With this knowledge, one may produce any type radiograph desired.

If we study a good radiograph we know at once that it includes a combination of the above factors. Everyone agrees that there should be a *minimum of distortion, a maximum of detail,* and *sufficient contrast* to make detail more plainly visible. There is a difference of opinion as to what *degree of density* may be most desirable. There are conditions in which *distortion* plays an important part and other conditions in which distortion, within reason, is of little importance.

Figure 7.1. The penetrating power of x-rays. Scheme A shows x-rays of long wave length being absorbed by the object. In B, x-rays of short wave length penetrate the object and expose the film (remnant radiation). In C, increasing the number of x-rays by the Ma.S. factor increases the number reaching the film, and more silver in the film is exposed than in B.



DENSITY

Density, which is due to the accumulation of *black metallic* silver, is the general blackening of the radiograph that appears after exposure by radiation and subsequent processing. Variations in density may exist in a series of radiographs and all of them be of good quality. Correct density is a matter of personal choice; however, all densities of the radiograph should transmit some visible light.

Density is a measure of the *quantity* of radiation absorbed by the film. The quantity is made up of *primary, remnant,* and *secondary* radiation.

Primary radiation

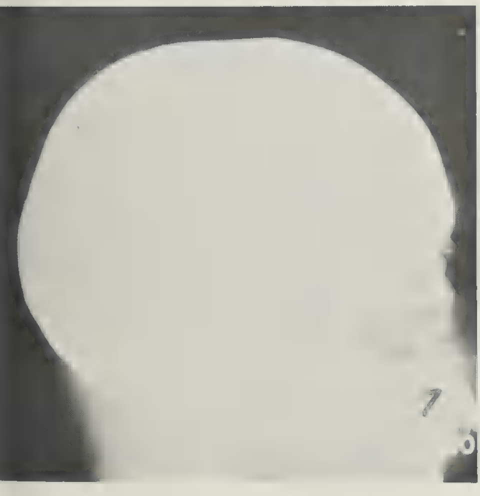
The amount of primary radiation is regulated by the quantity of current in milliamperes (Ma.) flowing through the tube for a definite length of time in seconds (s.), usually referred to as Ma.S.

Remnant radiation

Remnant radiation is that radiation which penetrates an object and emerges to expose the film.

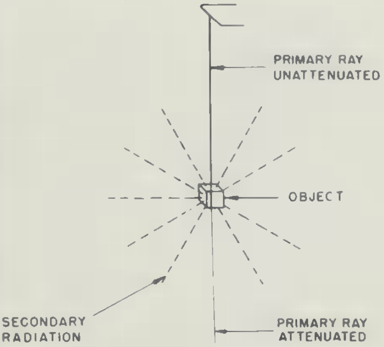
Secondary radiation

When a primary beam of x-rays penetrates an object, some of the x-rays are absorbed and some pass directly through; a considerable percentage, however, are scattered in all directions. These scattered rays comprise what is known as secondary radiation. Since the x-rays that are thus deflected



gure 7.2. Radiograph of lateral skull, for which the enetrating power (Kv.P) has been too low.

Figure 7.3. How primary radiation causes secondary radiation. The secondary radiation is set up in a spherical shape. It is characteristic of the material in which it arises and is of longer wave length than the primary ray. The higher the Kv.P., the more secondary radiation generated.



SECONDARY RADIATION IS SET UP IN A SPHERICAL SHAPE, IS CHARACTERISTIC OF THE MATERIAL IN WHICH IT ORIGINATES AND IS OF A LONGER WAVE LENGTH (LESS PENETRATING) THAN THE PRIMARY RAY. THE HIGHER THE KvP THE GREATER THE AMOUNT OF SECONDARY RADIATION GENERATED.

from their path are radiographically effective, they cause a general *haziness* or *fog* on the film. Secondary radiation is considered objectionable to good radiographic quality, since it overcasts the image with a supplemental density and obscures image detail. The problem of secondary radiation fog is minor in radiography of thin parts, but when thick parts are radiographed, some means of controlling the amount of secondary radiation must be employed. Attempts to use very low kilovoltage to control the amount of secondary radiation fog usually result in the use of x-rays with too low a penetrating power (see Figure 7.2).

The most effective way to eliminate secondary radiation is through the use of a Potter-Bucky diaphragm or stationary grid. The use of cones can also reduce secondary radiation. See Figures 7.4, 7.5, 7.7, and 7.8.

The density of the radiograph is influenced by the quantity of radiation that reaches the film. The amount of primary radiation is regulated by the quantity of current in milliamperes flowing through the tube for a definite length of time in seconds. The product of milliamperage and time is referred to as milliampere seconds (Ma.S.). See Table 6.12.

Density is affected by a number of things. Among them are: thickness of part, tissue opacity, pathology, respiration, distance, secondary radiation fog, old film, screen type or non-screen film, chemicals, cone, stereo shift, Kv.P., filters, compression binders, white light, or any form of radiation, automatic or manual processing, type of grid, and efficiency of equipment.

We can say, in general terms, that density refers to the lighter or darker appearance of the film. Either Ma., time, Kv.P., or distance may be used to control density. The distance factor is rarely used because it introduces the element of distortion. The Ma.S. (Ma. times the time) controls density *provided* we have sufficient penetration (Kv.P.). The Kv.P. factor may also be used to alter density. Increasing the developing time can alter density, but is not recommended. The temperature of the developing solution affects

Figure 7.4. P.A. view of chest, without grid.

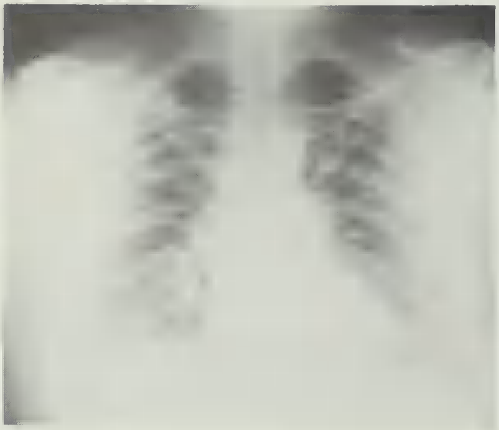
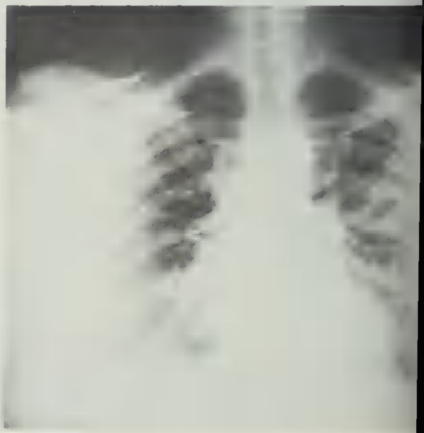


Figure 7.5. P.A. view of chest, with grid



density, but is not considered a practical means of control. Focal-spot damage affects density as well as contrast.

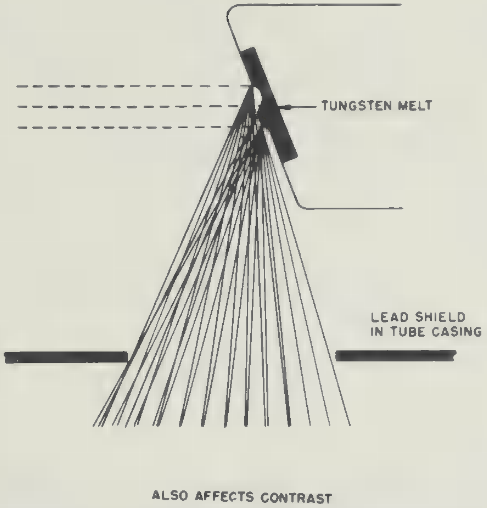


Figure 7.6. The effect of damage to the focal spot. The enlarged source of light and other changes affect density and contrast.

7.7. Radiograph taken with both cone and grid.

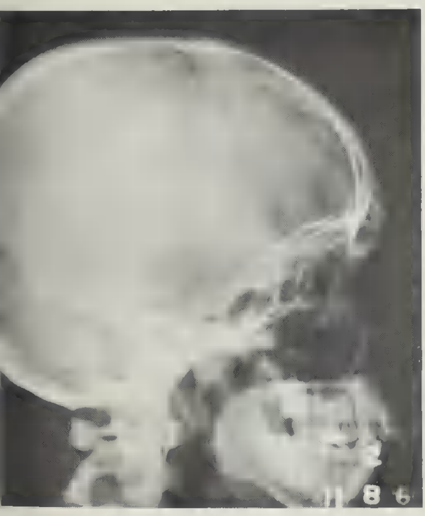
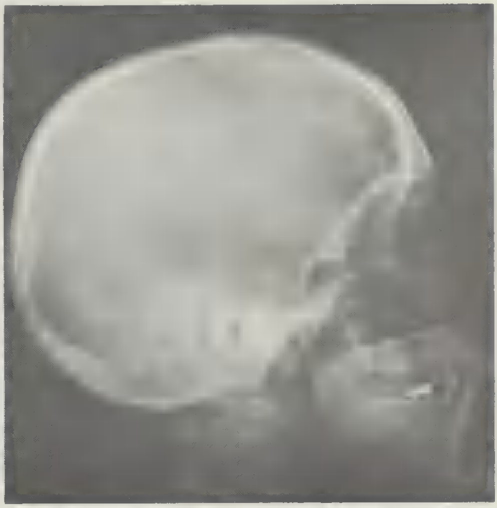


Figure 7.8. Radiograph taken with cone but without grid.



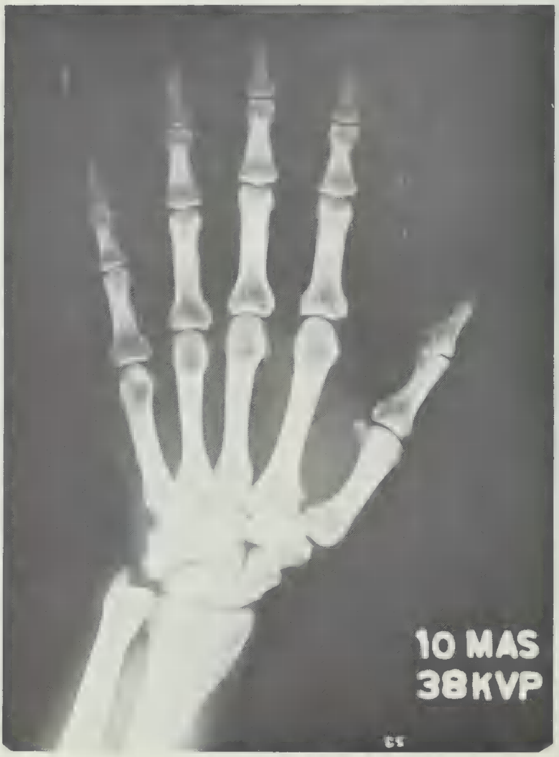
CONTRAST

Radiographic contrast is defined as the percentage of difference between the extreme *blacks* and *whites* in the radiograph. As contrast is *decreased,* the percentage of difference between various densities on the film is reduced. (This does not refer to the *background* in relation to the *anatomical* part.)

Opinions as to the amount of contrast desired do not seem to vary as much as those concerning radiographic density, yet a considerable range of opinion does exist. For this reason it seems inadvisable to set any definite degree of contrast as a standard.

The old rule "the lower the kilovoltage and the higher the Ma.S., the greater the contrast" is true only *within certain limits.* For example, the kilovoltage could be so low that we would have *insufficient contrast*; to put it another way, we can say of such a radiograph that the degrees of brightness over the area being examined are too nearly the same for satisfactory discrimination (Figure 7.2). Perhaps a better term here would be *insufficient*

Figure 7.9. P.A. radiograph of the hand, an example of short-scale contrast.

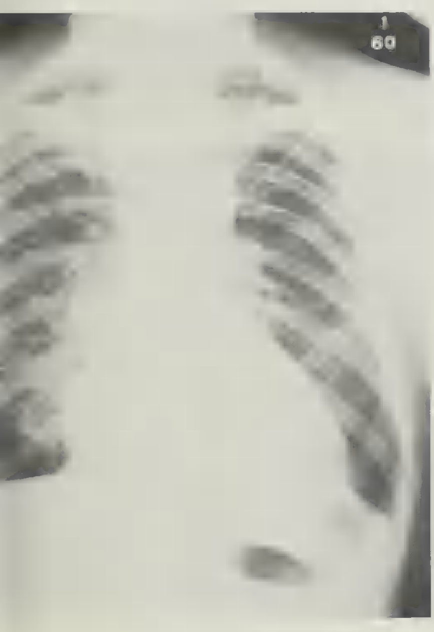


density, since we do not have enough black and white in the image to give us contrast and we therefore have no detail.

General differences in tone value may be divided into two arbitrary scales of contrast. As radiographic contrast increases, the difference in tone value between adjacent densities becomes greater or more abrupt. The densities that represent the thinner portions of the part increase and may become opaque. This increase may be carried to excess so that the densities which represent the thick parts become very low, to the extent of not recording detail at all. For example, when low kilovoltage is used for thin parts *greater contrast* results between radiographic images of the bones and the flesh. However, a point may be reached in which radiographic detail in the thinner portions, such as the subcutaneous tissues and muscles, is obliterated by opaque silver deposits; and some bone detail may be lost because the denser bone tissue absorbs so much radiation that little remnant radiation reaches the film. Visibility of detail in those areas is diminished and *short scale* or *high contrast* results. As radiographic contrast decreases, the brightness differences in tone value between densities become less; consequently, a greater number of tones are visualized over the entire image. The transition between tones is gradual since only small density differences occur. This type is known as *long-scale* or *low contrast.*

Kilovoltage governs the scale of contrast in the image and influences the production of secondary radiation.

Radiographic contrast is the product of two factors: (1) *film contrast,* which is inherent in film manufacture and developing process, (2) *subject contrast,* which is the result of the absorption of the radiation by the patient. Radi-



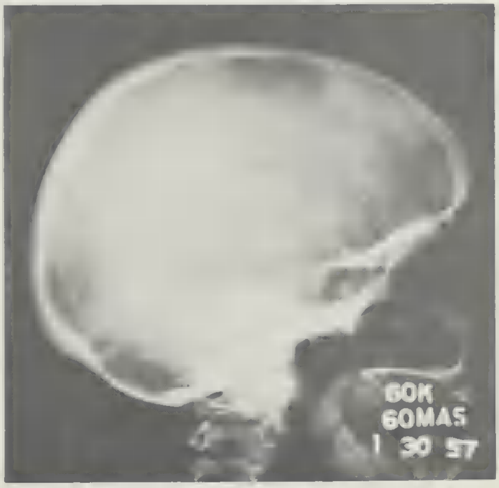


Figure 7.10. Examples of short-scale contrast.

ographic contrast can be controlled by altering either one or both of these contributing factors. Subject contrast can be readily altered by changing the *quality* of radiation or *kilovoltage*; it is good technique to *standardize* the film and development and leave the control of the contrast in the finished radiograph to the single factor—*kilovoltage*.

Short-scale contrast

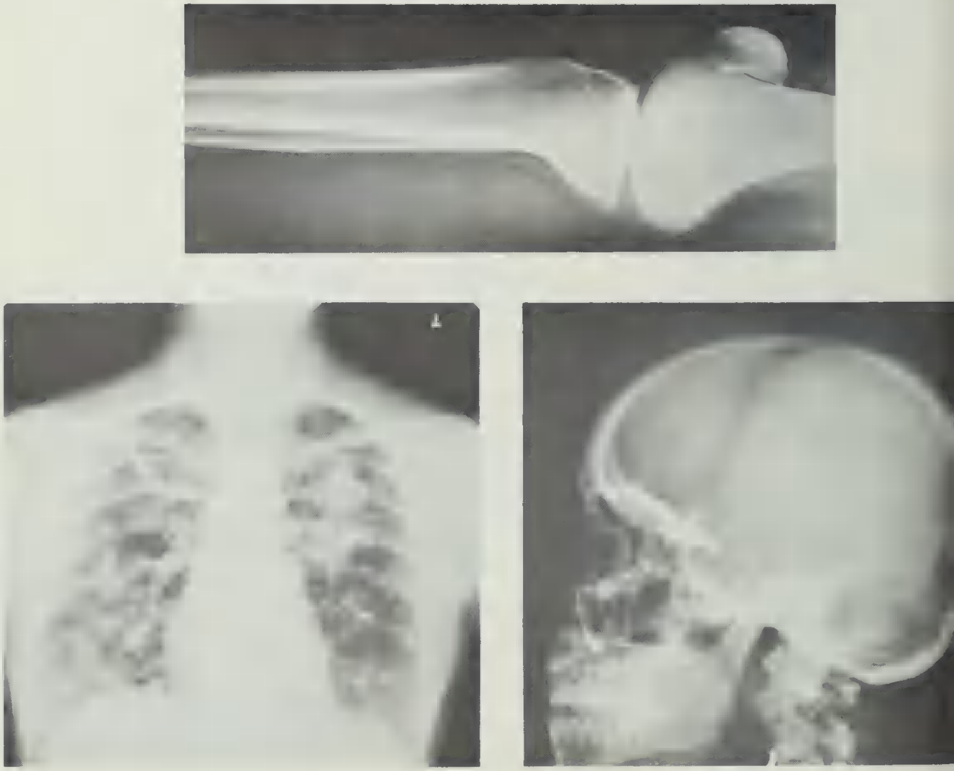
In a radiograph of a body part with a short range of widely different intermediate translucent densities, short-scale contrast exists. Such radiographs possess instant eye appeal.

On the whole, a radiograph with short-scale contrast (low kilovoltage) is incomplete, for details that represent the thinner and thicker portions of the body are not always shown. Typical radiographic examples of short-scale contrast are shown in Figure 7.10.

Long-scale contrast

Long-scale contrast makes possible the visualization of small image density. The short wave length (higher kilovoltage) radiation effects greater

Figure 7.11. Examples of long-scale contrast.



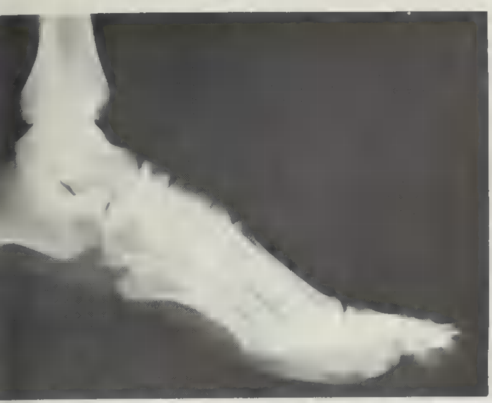


Figure 7.12. Radiograph of the lateral ankle and foot, made with regular film and screens.

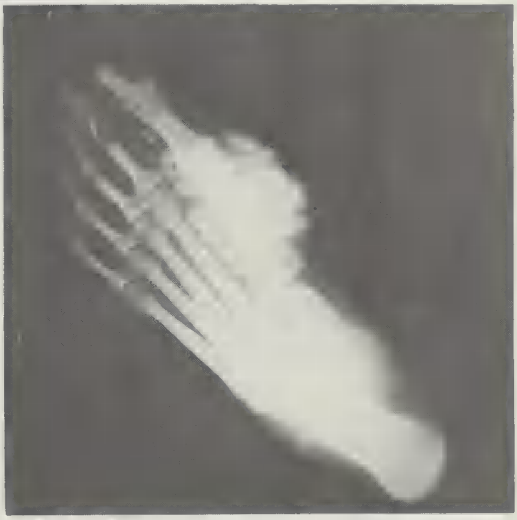


Figure 7.13. A.P. view of the entire foot, made with non-screen film.

penetration of the tissues and results in an abundance of remnant radiation of varying intensity that, in turn, produces a large number of translucent densities. The contrast scale, however, should never be so long that differentiation between structures is difficult (kilovoltage too high). Typical radiographic examples of long-scale contrast are shown in Figure 7.11.

Other factors influencing contrast

As stated previously there are a number of factors other than *kilovoltage* that influence radiographic contrast. They are (*a*) developer contrast, (*b*) film contrast, and (*c*) tissue contrast. These factors can, however, be regulated so that they can be considered constants and thus standardized.

Other factors affecting contrast are: processing (automatic vs. manual), temperature of the developer, screens, focus–film distance, cones, grids, pathology, compression, opacity of the part, respiration, Ma.S., secondary-radiation fog, filters, old chemicals, white light or any form of radiation.

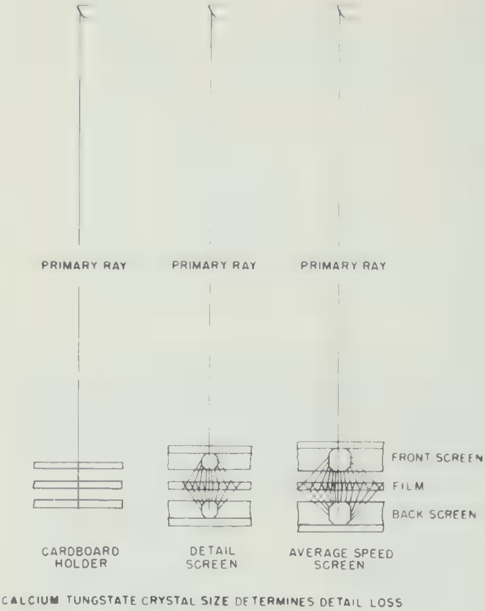


Figure 7.14. Effect of screens on detail. Though contrast is heightened by screens, some detail is lost, depending on the size of the crystals of calcium tungstate.

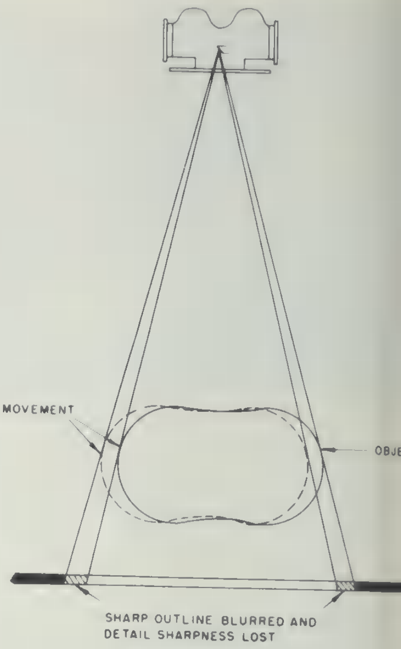
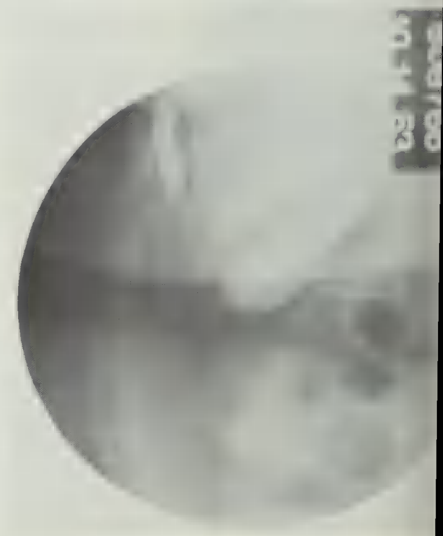


Figure 7.15. Effect of motion on detail. See Figures 6.9 and 6.10.

Figure 7.16. Radiograph (gallbladder) with a large port of entry, on a patient weighing 270 pounds.

Figure 7.17. Radiograph of the patient of Figur taken with a small port of entry – a cylinder con



Developer contrast

Two types of developers are in common use. The regular type is a sodium carbonate developer that produces long-scale contrast in the radiographic image. The other is one containing a more active alkali, sodium hydroxide, which produces greater contrast in the image as compared to that produced by regular developer. Since the type of contrast produced by the developer can be changed in some measure by the *time* and *temperature* of development, the maximum radiographic contrast from either type of development will be obtained only when *full* development is employed.

Film contrast

Screen-type film has an inherent higher contrast when exposed with screens than when the same film is exposed by direct radiation at the same kilovoltage.

Direct exposure films (non-screen) have a thick emulsion, and provide a higher contrast than the screen-type film when direct exposures are employed for both, using the same kilovoltage. At the *same* kilovoltage, non-screen film is about *three* times faster than screen-type film under the same conditions.

DETAIL

Detail can be considered a visual quality that depends, first, upon *sharpness* and, secondly, upon *radiographic contrast.*

When structures are sharp and clearly delineated, and when the density differences between these structures (contrast) are sufficient for the eye to distinguish one from another easily, the radiograph is said to have good detail. Sharpness of detail is often referred to as definition.

The size of the x-ray tube focal spot has a great effect on detail; however, with present day rotating-anode tubes this does not present too much of a problem.

When an image is projected from a pin-point light source, the borders of the image are sharp, but if the light source is a larger surface such as a large focal spot of an x-ray tube, the image is ill-defined at the *outer edge* because of *penumbra* formation. To reduce the penumbra the focal-spot size must be small, and the object–film distance as close as possible. The focus–film distance should be as long as possible. See Figure 7.19.

Generally the smaller the size of the focal spot, the sharper the detail. Close subject–film contact; non-movement of the part, film, or tube during exposure; and good screen contact are essential for good detail.

The use of screens results in a loss of detail; however, it is impractical to use non-screen film on heavy parts in order to obtain better detail.

Detail is dependent primarily upon:

a. Size of effective focal-spot
b. Focus–film distance
c. Object–film distance
d. Immobilization of the part
e. Size of port of entry of primary beam
f. Speed of screens
g. Screen-film contact

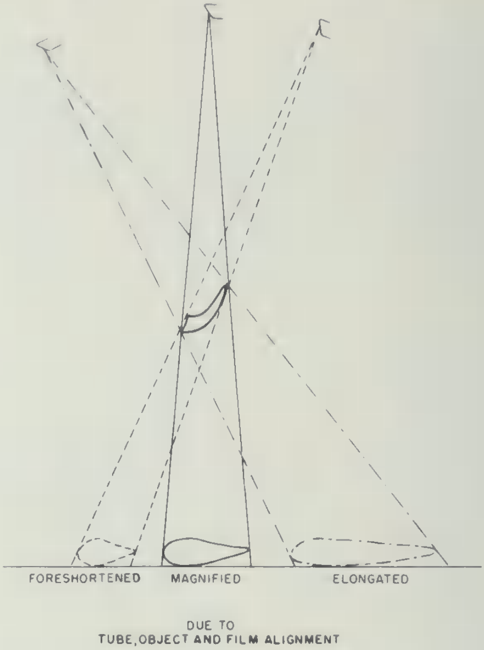


Figure 7.18. Types of distortion caused by inaccuracies in aligning the tube, the object, and the film.

Other factors affecting detail are: overexposure or underexposure with Ma.S. or Kv.P., filters, respiration, fog, stereo shift, grid "cut-off," Bucky, pathology, and compression.

DISTORTION

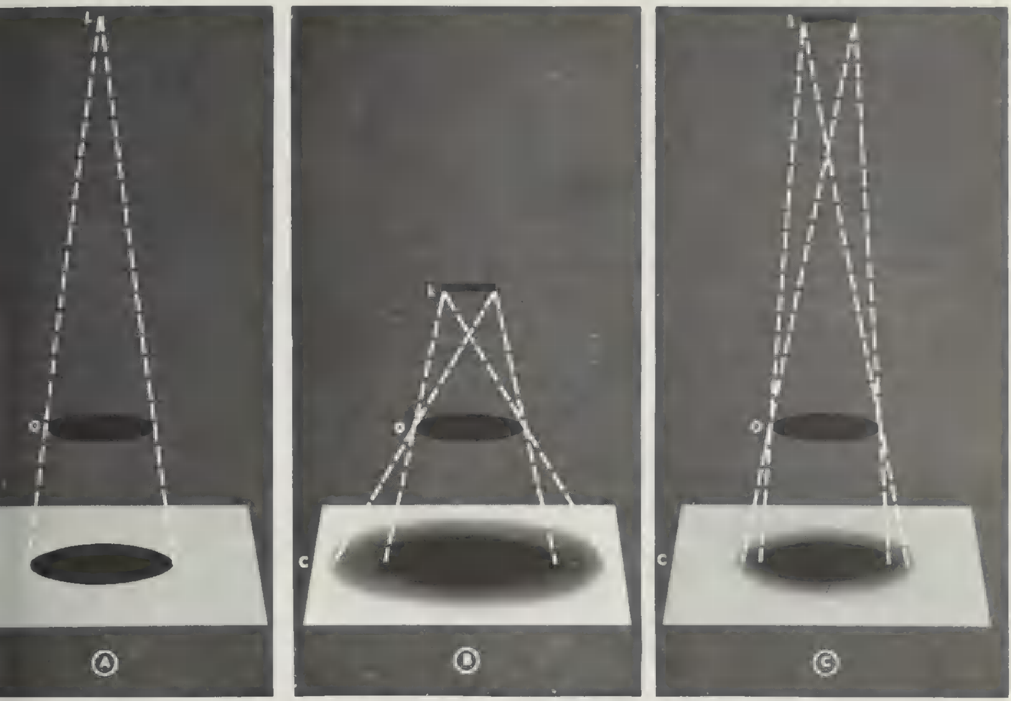
The smaller the source of radiation and the nearer the object to the film, the sharper and more accurate the image.

Geometric principles

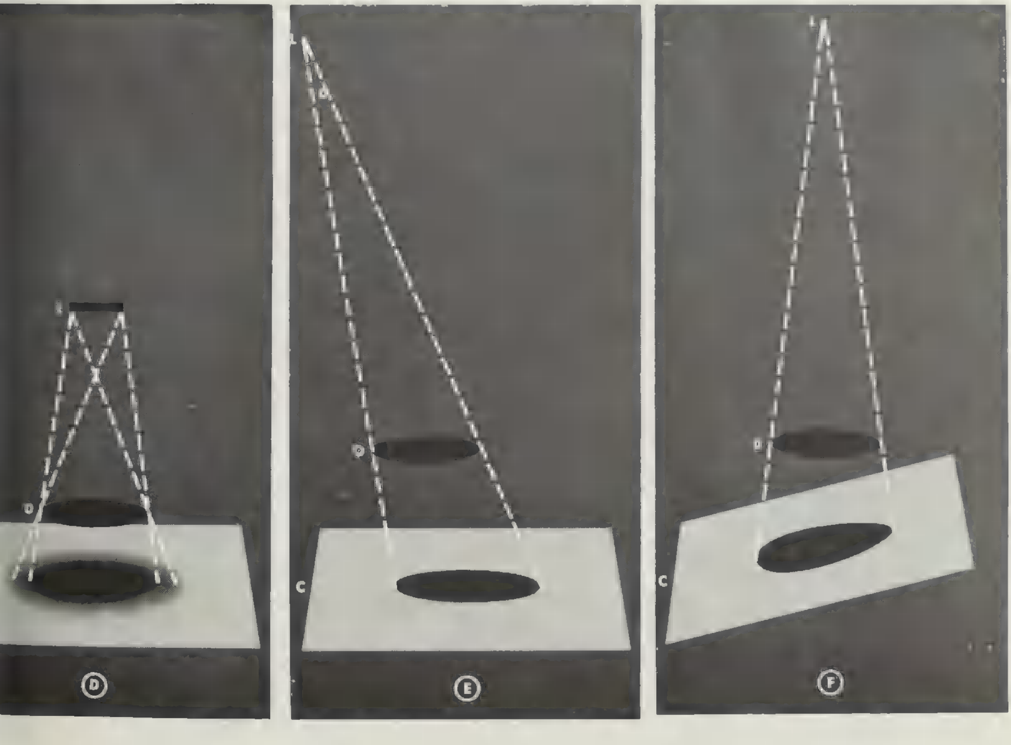
X-rays and gamma rays obey the common laws of light—their shadow formation may be explained in a simple manner in terms of light. The analogy between light and x-rays or gamma rays is not perfect, but the same geometric laws of shadow formation hold for both radiations.

Suppose as in Figure 7.19 that there is light from a point (*L*) falling on a white card (*C*), and an opaque object (*O*) is interposed between the light source and the card. A shadow of the object will be formed on the surface of the card.

This shadow cast by the object will naturally show some *enlargement* because the object is *not in contact* with the card; the *degree of enlargement* will vary according to the relative distances of the object from the card and from the light source. *The form of the shadow* also may differ according



gure 7.19. Geometric principles: the effects of changing the relative positions of source, object, and card

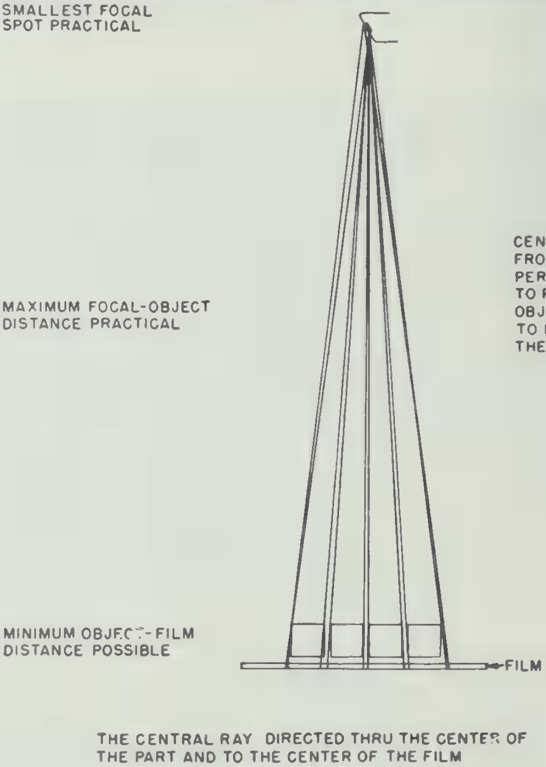


to the angle which the object makes with the incident light rays. Deviations from the *true shape* of the object as exhibited in its shadow image are called *distortion.*

The degree of sharpness of any shadow depends upon the size of the source of light and upon the position of the object between the light and the card – whether nearer to or farther from one or the other. The shadows cast when the source of light is not a small area are not perfectly sharp because each point in the source of light casts its own shadow of the object; all these overlapping shadows, since they are slightly displaced from each other, produce an ill-defined image. Figures 7.19A–F show the effects of changing the relative positions of source, object, and card. The following conditions must be fulfilled to produce a sharp, true shadow of the object.

1. The source of light should be small. Compare Figures A and C.
2. The source of light should be as far from the object as practicable. Compare Figures B and C.
3. The recording surface should be as close to the object as possible. Compare Figures B and D.
4. The light rays should be directed perpendicularly to the recording surface. See Figures A and E.

Figure 7.20. The best positioning of source, object, and film.


SMALLEST FOCAL SPOT PRACTICAL
MAXIMUM FOCAL-OBJECT DISTANCE PRACTICAL
CENTRAL RAY FROM TUBE PERPENDICULAR TO PLANE OF OBJECT AND TO PLANE OF THE FILM
MINIMUM OBJECT-FILM DISTANCE POSSIBLE
FILM
THE CENTRAL RAY DIRECTED THRU THE CENTER OF THE PART AND TO THE CENTER OF THE FILM

DISTANCE

X-ray intensities can be altered by moving the tube from or toward the plane of the image. Fuchs suggests that a light bulb be used to demonstrate this fact.* With no other illumination in the room, move a single light toward this printed page. You will find that the closer the light is to the page, the more brightly the page is illuminated. Exactly the same thing occurs with x-rays: as the distance from the object to the source of radiation is decreased, the intensity at the object increases, and vice versa.

Both changes in milliamperage and changes in distance are very similar in their effect upon the intensity of the image. It is important to know that these changes in intensity affect the over-all image.

When the x-ray tube output is held constant, the x-ray intensity reaching the subject is governed by the distance between the x-ray tube and the subject, varying inversely with the square of this distance. Since x-rays conform to the laws of light, they diverge when they are emitted from the anode and cover an increasingly larger area with lessened intensity as they travel from their source. In Figure 7.21 this principle is illustrated. In this example it is assumed that the intensity of the x-rays emitted at the anode (*A*) remains constant, and that the x-rays passing through the aperture (*B*) cover an area of 4 square inches on reaching the recording surface C_1, which is 12 inches (*D*) from (*A*). Then, when the recording surface C_1 is moved 12 inches farther from the anode to C_2, so that the distance between *A* and C_2 is 24 inches (*2D*), or twice the distance between *A* and C_1, the x-rays will cover 16 square inches—an area 4 times as great as that at C_1. It follows, therefore, that the radiation *per square inch* on the surface at C_2 is only one quarter that at the level C_1. Thus the exposure that would be adequate at C_1 must be increased 4 times in order to produce at C_2 a radiograph of equal density.

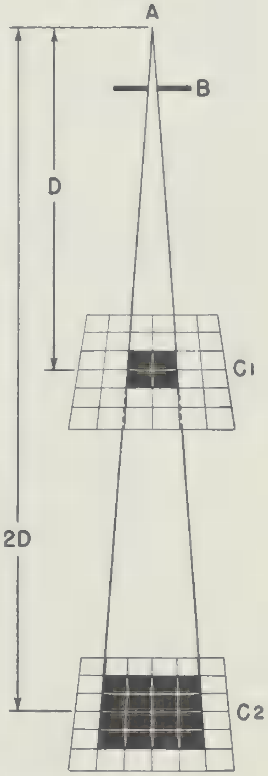


Figure 7.21. The inverse square law.

The inverse square law

The inverse square law is one of the most important and most useful laws in standardized radiography, since factors that give a satisfactory radiograph at one distance may be known, and if it is desired to increase or decrease the distance, the voltage and milliamperage may be kept constant and the new milliampere seconds calculated by this formula. The inverse square law may be stated thus:

$$\frac{I_1}{I_2} = \frac{d_2^2}{d_1^2}$$

Where I_1 and I_2 are the intensities at distances d_1 and d_2 respectively. The inverse square law may be stated thus:

The intensity of radiation varies inversely as the square of the distance.

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*A. W. Fuchs, *The Fundamentals of Radiography*, Eastman Kodak Co., 1953.

The inverse square law can be used in establishing formulas for calculating various exposure-distance relationships. For example, the Ma.S.–distance formula (see pages 125–26) can be set up because we know how the intensity of radiation will be affected if the distance between the tube and target is varied. In this case, the Ma.S. *in use* is to the *new* Ma.S. as the *old distance* squared is to the *new distance* squared. Figure 6.7 is a radiograph of a chest made at 72 inches. Figure 6.8 is the same patient radiographed at 36 inches with the reduction in Ma.S. computed by the formula based on the inverse square law.

REVIEW

THE RADIOGRAPHIC QUALITIES: DENSITY, CONTRAST, DETAIL, DISTORTION

Controlling factors			
Density	*Contrast*	*Detail*	*Distortion*
1. Ma.S.	1. Kv.P.	1. Motion	1. Focus-film distance
2. Kv.P.	2. Ma.S.	2. Focal spot	2. Object-film distance
		3. Focus-film distance	3. Tube alignment
		4. Object-film distance	

Factors directly affecting		*Factors indirectly affecting*	
Density	*Contrast*	*Density*	*Contrast*
1. Thickness of part	1. Bucky	1. Bucky	1. Thickness of part
2. Opacity	2. Cones	2. Cones	2. Opacity
3. Pathology	3. Screens	3. Screens	3. Pathology
4. Compression	4. Cardboard holders	4. Cardboard	4. Compression
5. Respiration	5. Filters	5. Filter	5. Respiration
6. Focus-film distance	6. Film	6. Films	6. Focus-film distance

Factors affecting both density and contrast
1. Processing
2. Radiographic efficiency of equipment

KILOVOLTAGE

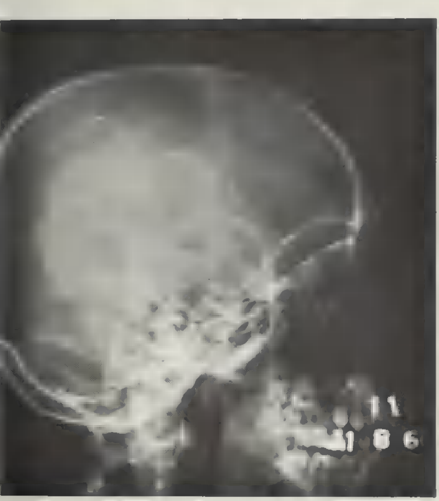
Of all the four primary factors in the production of a radiograph (milliamperage, time, kilovoltage, and distance) kilovoltage has the greatest effect upon the radiographic image. Kilovoltage *influences the quality of the radiation, determines the contrast in the image, and influences exposure latitude, radiographic density, and secondary radiation fog.*

According to Seemann and Splettstasser, a good radiograph is the net result of favorable conditions with respect to two basic physical factors: *contrast* and *definition.* No one can say that *definition* is more important than *contrast,* or vice versa. In a radiograph with insufficient contrast, brightnesses over the areas are too nearly the same for satisfactory discrimination, while with poor definition, areas of one density merge into another so gradually that the diffuse image cannot be interpreted.

Early radiographic techniques employed the use of higher kilovoltages because with low-current equipment, penetration was of paramount importance. With the development of equipment with higher milliamperage and faster film and screens, radiographic technique swung to the use of lower kilovoltages, higher milliamperage, and high film contrast. Now the trend is back to the use of higher kilovoltages, low milliampere-second values which permit lower patient dosage with the production of better diagnostic images. Notable among the contributors to the standard approach to this technique was the late Arthur W. Fuchs. The use of higher kilovoltages in radiography caused the factors of *secondary radiation fog, cones,* and a *higher ratio grid* to assume great importance.

Overexposure with kilovoltage

An overexposed radiograph is gray and flat. The contrast and detail of the image are obscured. Under normal conditions, a reduction of 10 to 15 Kv.P. will improve the radiographic quality appreciably.



7.22. An overexposed radiograph due to sive Kv.P.

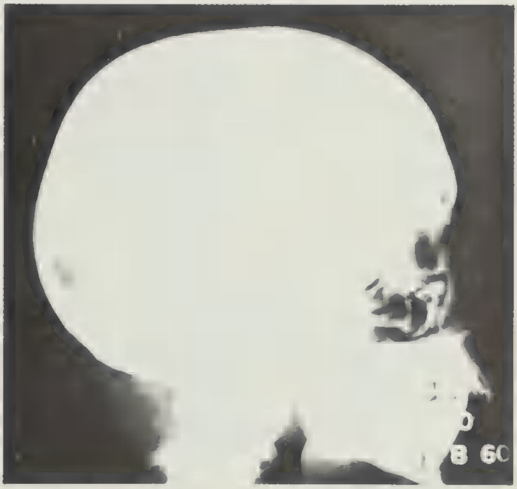


Figure 7.23. Underexposure due to inadequate Kv.P.

Underexposure with kilovoltage

A radiograph underexposed because of inadequate kilovoltage, because of the lack of penetration, is characterized by a *chalky appearance* and *insufficient contrast.* An increase of 10 to 15 Kv.P. will improve the radiographic quality; however, a slight adjustment in milliampere-seconds may be necessary to provide the optimum film quality.

Insufficient kilovoltage

It is not practical to use excessive milliampere-second values when using a kilovoltage that is inadequate to penetrate the part. High Ma.S. values and low Kv.P. are dangerous to the patient.

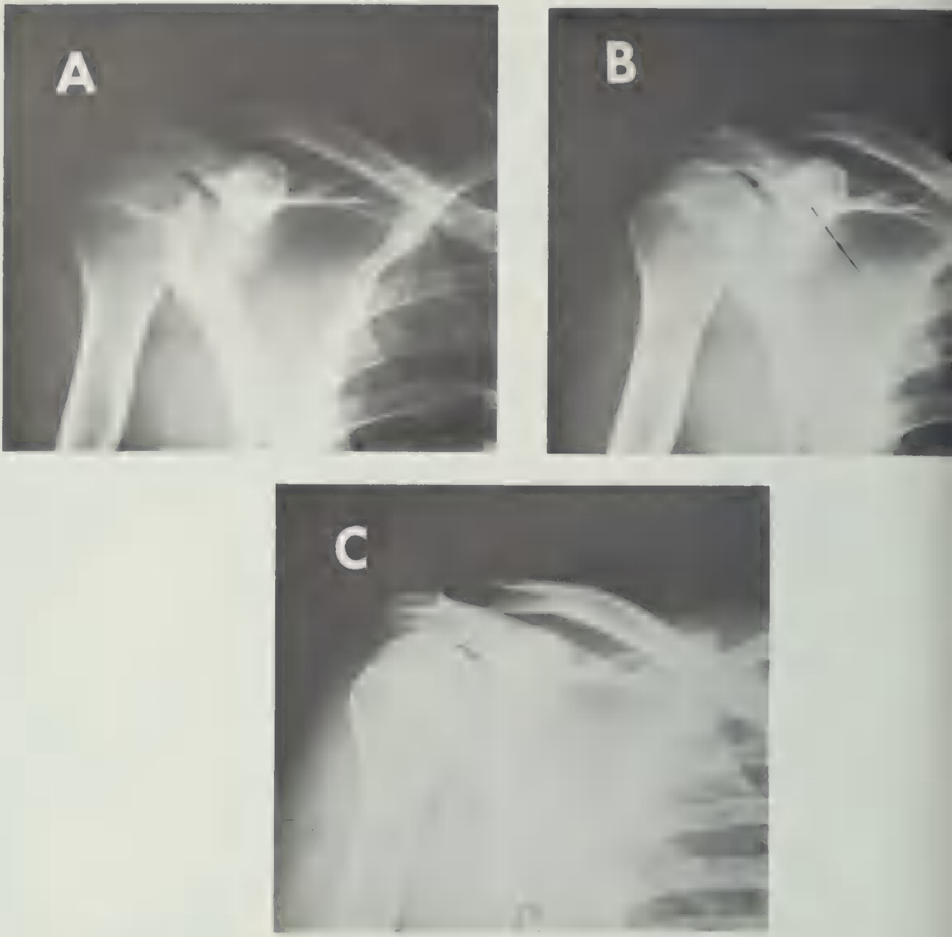


Figure 7.24. A.P. view of shoulder. A shows overexposure, corrected in B by reducing the Kv.P. by 10. In C, too low a Kv.P. results in underexposure.

Kilovoltage and contrast

When secondary radiation and Ma.S. are controlled, kilovoltage becomes the factor of radiographic contrast. With contrast, we have detail in the image; in fact, detail in the image is dependent upon radiographic contrast.

General differences in tone value may be divided into two arbitrary scales of contrast. As radiographic contrast increases, the brightness in tone value between adjacent densities becomes greater or more abrupt. The densities that represent the thinner portions of the part increase and may become opaque. This increase may be carried to excess so that the densities which represent the thick parts become very low, to the extent of not recording detail at all. Visibility of detail in those areas is diminished and *short scale* or *high contrast* results. As radiographic contrast decreases, the brightness differences in tone value between densities become less; consequently, a greater number of tones are visualized over the entire image. The transition

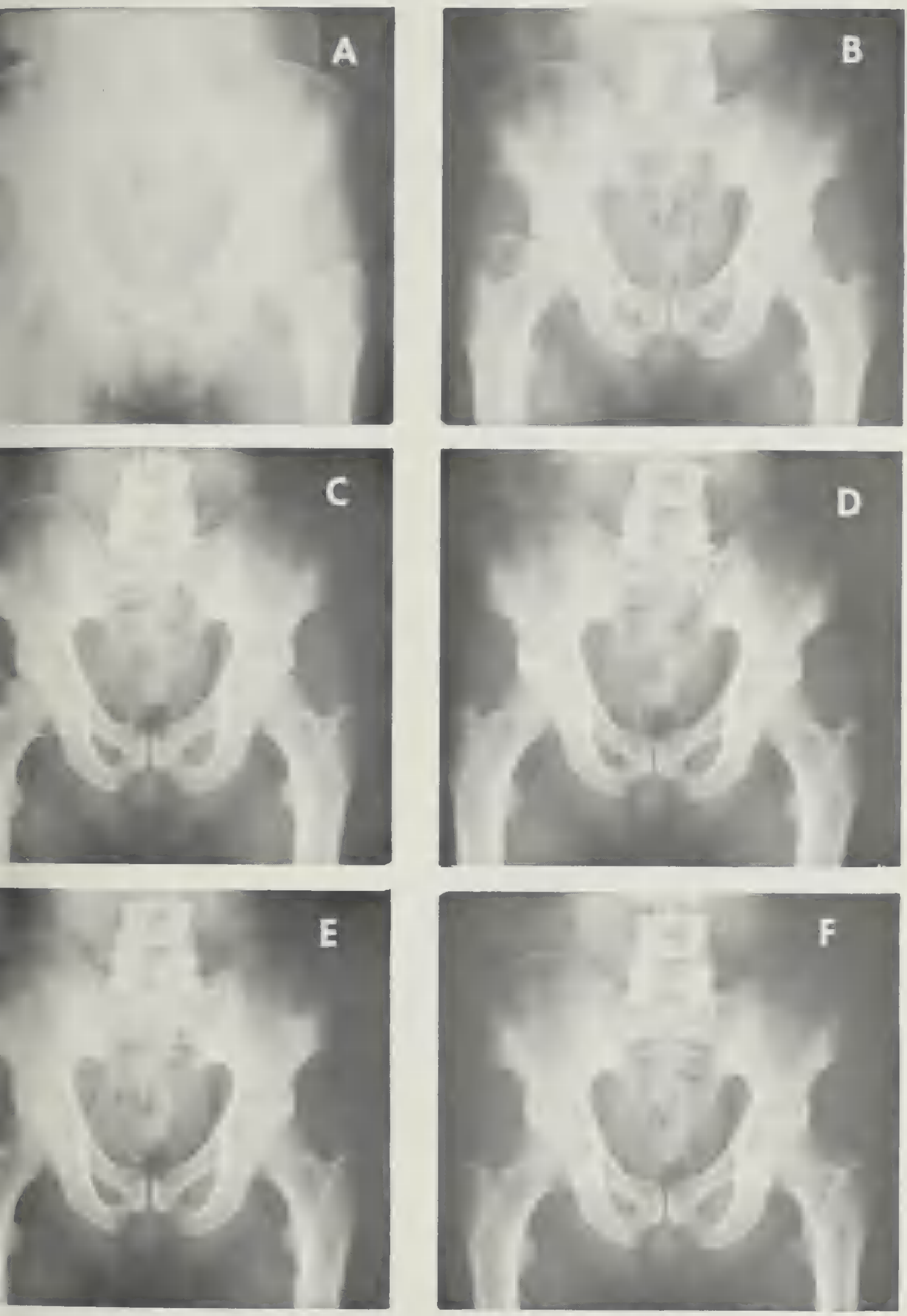
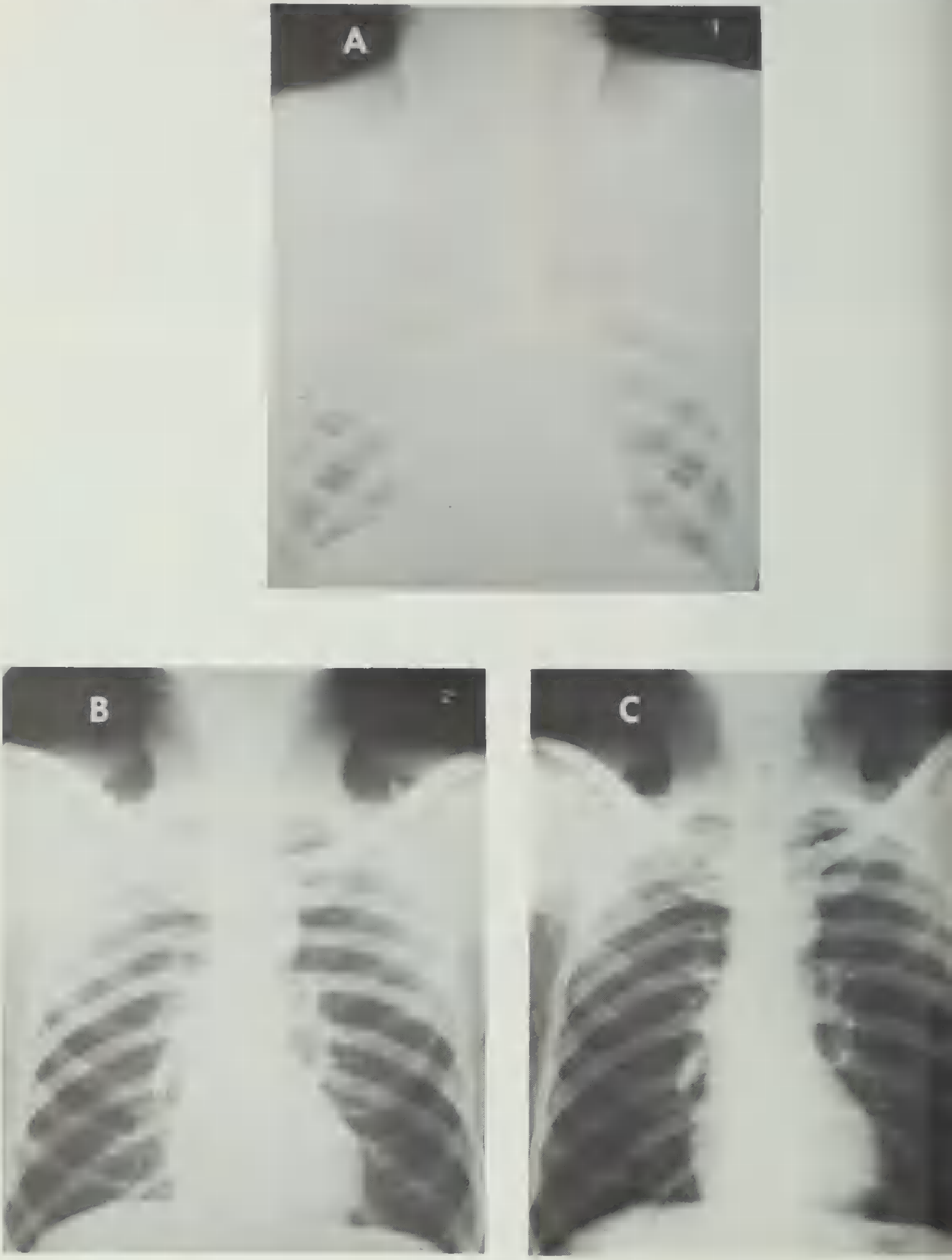


Figure 7.25. These six A.P. views of a pelvis show a broad exposure latitude: A–20 Ma.S.; B–30 Ma.S.; C–40 Ma.S.; D–50 Ma.S.; E–60 Ma.S.; F–70 Ma.S.

between tones is gradual since only small density differences occur. This type is known as *long-scale* or *low contrast.*

Figure 7.26. These P.A. views of the chest show a narrow exposure latitude, at 50 Kv.P.: A – 5 Ma.S.; B – 10 Ma.S.; C – 20 Ma.S.



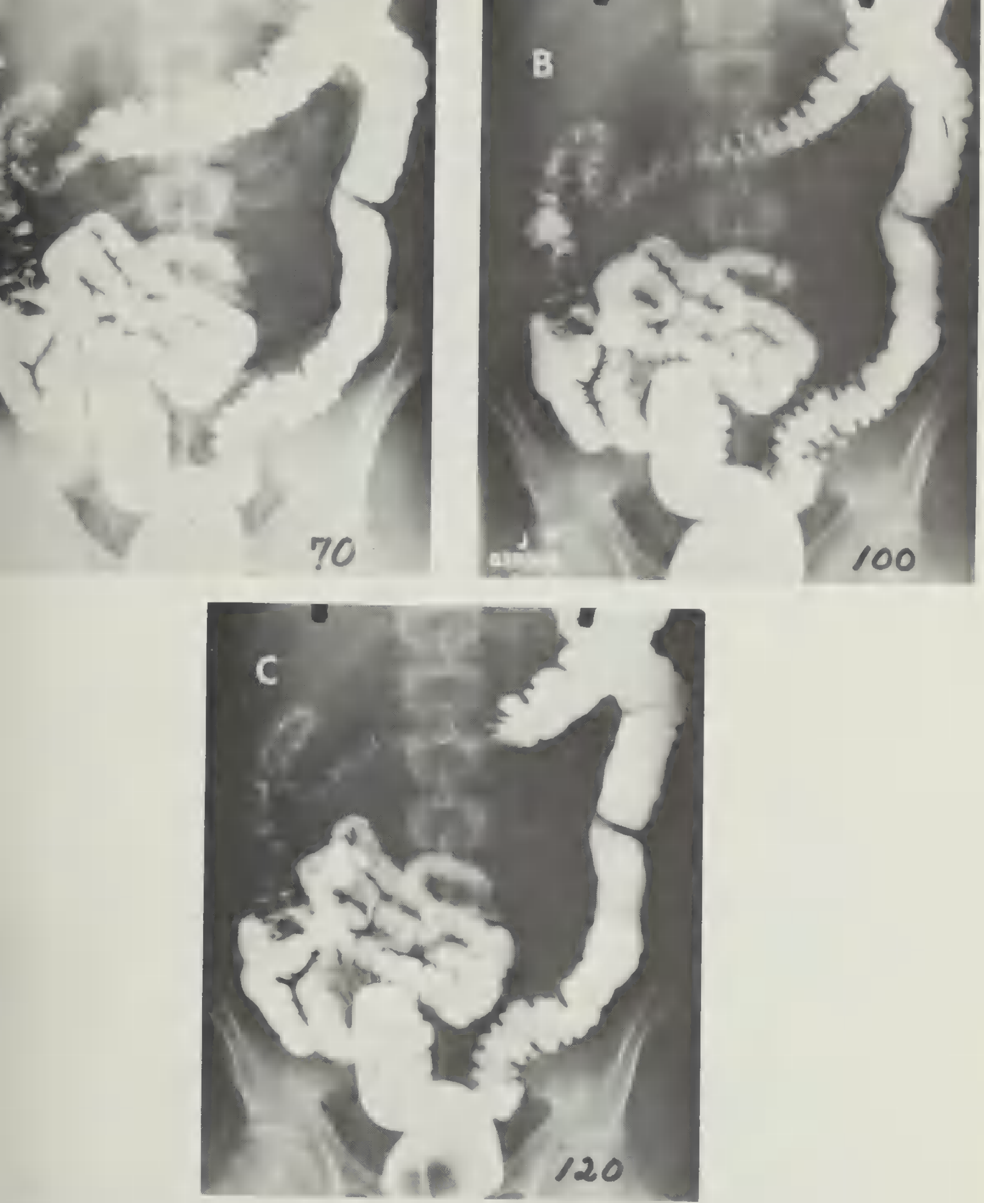


Figure 7.27. The effect of grids. Radiographs of a colon—A at 70 Kv.P. and 60 Ma.S.; B at 100 Kv.P. and 60 Ma.S.; and C at 120 Kv.P. and 50 Ma.S. A and B were made with an 8-to-1 grid; C, with a 16-to-1 grid. Note the detail recorded in B and C that is missing in A.

Kilovoltage and latitude

Exposure latitude is the range between maximum exposure and minimum exposure that can be used to produce a diagnostically acceptable radiograph. Exposure latitude varies with the kilovoltage applied and whether or not screens or direct exposures are employed. With long-scale contrast technique, produced by fixed kilovoltage, the exposure latitude becomes wide, and wide errors in Ma.S. may be tolerated. With lower kilovoltages, short-scale contrast is produced, and the exposure latitude becomes narrow, and errors in exposure become more critical.

The only limit to the kilovoltage that can be used in radiography is the limitation imposed by contrast. The limiting voltage is the one at which the contrast scale has become so *long* that diagnosis becomes doubtful. The limitations of contrast have been recognized by all who have investigated the use of higher voltages for diagnosis. Investigation of the grids of various ratios was the starting point for such work since the *grid*, thus far, is the best means of reducing scattered radiation. Notable among the investigators of the grid and secondary radiation are Wisley, Trout, Groves, Slauson, Kelley, Seemann and Splettstasser.

The results of Trout and Kelley proved that the 16-to-1 grid gave a considerably higher degree of contrast at any voltage than did the 8-to-1 grid. The contrast was reduced as the voltage was increased, but by using the 16-to-1 grid it was possible to use a higher voltage and to retain a degree of contrast equal to that provided by the 8-to-1 grid at a lower kilovoltage. See Figure 7.27C.

One of the real gains was the reduction of the exposure to the patient as the kilovoltage was increased. The patient dosage can be still further reduced by the use of filters.

The reduction of scattered radiation with a grid requires that additional exposure be made to obtain a satisfactory radiographic image. This may be accomplished by raising the milliampere-seconds or kilovoltage; yet so rapid is the increase in penetration with increasing kilovoltage, and so effective is the removal of scattered radiation in increasing subject contrast, that one may actually attain higher contrast at high kilovoltage with a grid than at low kilovoltage without a grid. See Figures 8.29 and 8.30 below.

With small amounts of scattered radiation, an 8-to-1 grid is almost as useful as a 16-to-1 grid. A 16-to-1 grid absorbs appreciably more primary radiation than the 8-to-1 grid. The small gain in subject contrast in changing from 8-to-1 to a 16-to-1 grid technique might not be worth while for average thicknesses, because of the increased exposure required to make up for the higher absorption. The 16-to-1 grid should be used only when it offers a significant advantage by increasing the subject contrast. See Figure 7.27C.

There has been for years among technologists a commonly held fallacy that all radiographs made with high kilovoltage are necessarily gray and flat. It is possible to produce films of as good quality with high kilovoltage as with low kilovoltage. Radiographs made at various kilovoltage values, but with suitable compensation in milliampere-seconds, should be indistinguishable from each other in quality, except that one should be able to visualize an increased range of densities with high kilovoltage.

Figure 7.28 shows two exposures of the toes made on non-screen film. The anteroposterior projection was exposed at 50 Kv.P. and 25 Ma.S.; the lateral at 100 Kv.P., 10 Ma.S. Note the long range of densities from the skin to the phalanx and metatarsals. Figure 7.29 shows two exposures of the os calcis made on the same non-screen film, one exposure at 50 Kv.P., 60 Ma.S., and one exposure at 120 Kv.P. and 15 Ma.S. It will be noted that these exposures are comparable.

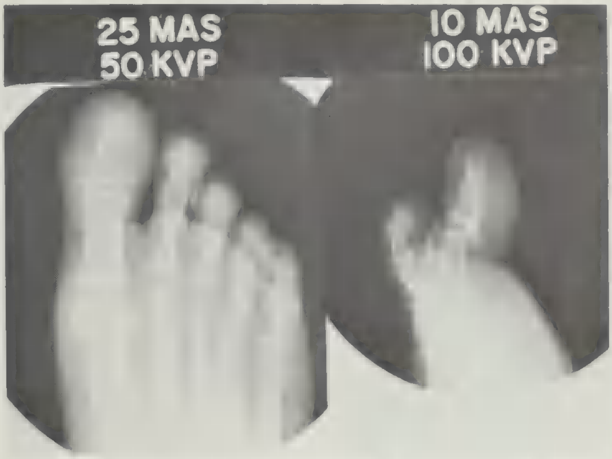


Figure 7.28. Two views of phalanges with exposures at different kilovoltages and compensation in Ma.S:

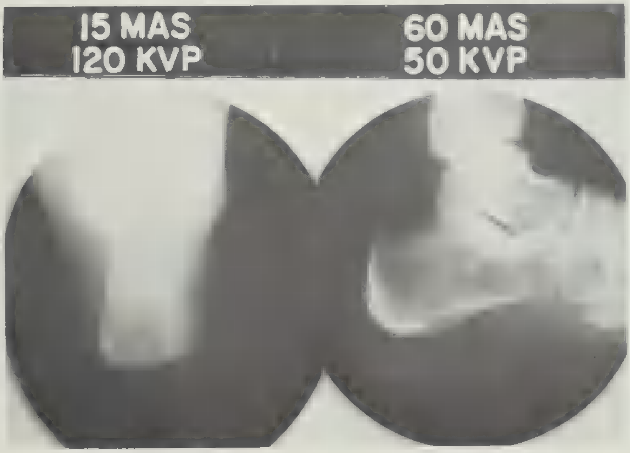
Kilovoltage: a review

Since kilovoltage plays such an important role in radiography, it might be well to review the influence of kilovoltage on radiographic exposure.

When all other factors are constant, *density changes with Kv.P.; Kv.P. governs the quality of radiation; Kv.P. governs penetration; Kv.P. influences the amount of secondary radiation fog; Kv.P. regulates exposure latitude; Kv.P. controls contrast:* low Kv.P. produces short-scale contrast, high Kv.P. produces long-scale contrast.

The use of the higher kilovoltages (above the usual variable kilovoltage techniques) provides greater exposure efficiency in routine radiography

Figure 7.29. Two views of os calcis: exposures made at high and low kilovoltages, with compensation in Ma.S.



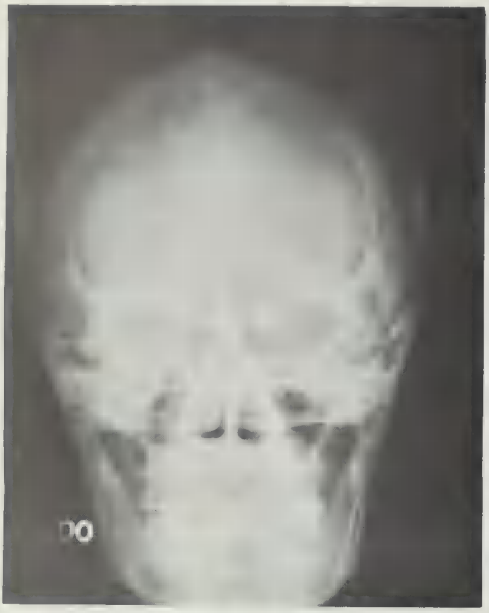


Figure 7.30. P.A. view of skull at 100 Kv.P.

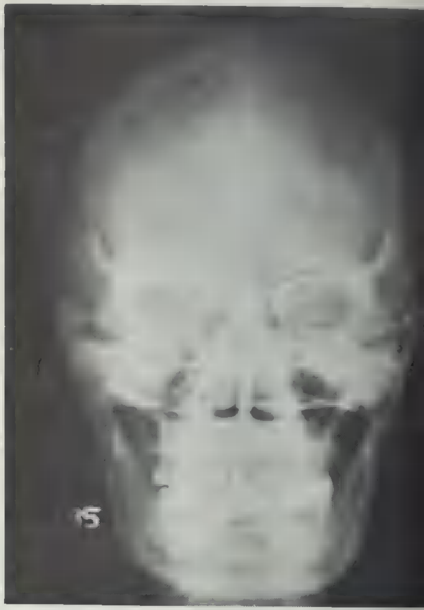


Figure 7.31. P.A. view of skull at 85 Kv.P

because details in all tissue are recorded as translucent densities. Soft-tissue detail is often better than that produced by lower kilovoltage (see Figure 7.28, radiograph of the toe at 100 Kv.P.).

The radiation dose to the patient is reduced as the kilovoltage increases and the milliampere-seconds decreases because the body absorbs less radiation than at lower kilovoltages.

Figure 7.32. Lateral view of skull with opaque medium at 85 Kv.P.

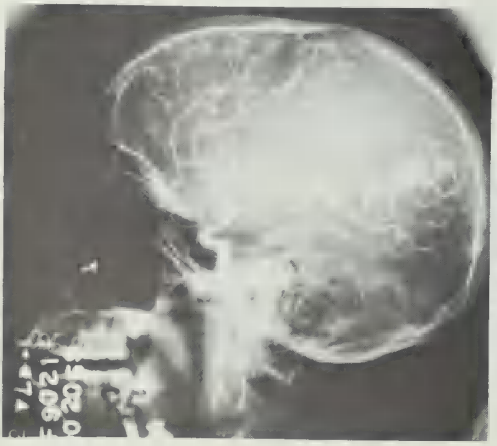
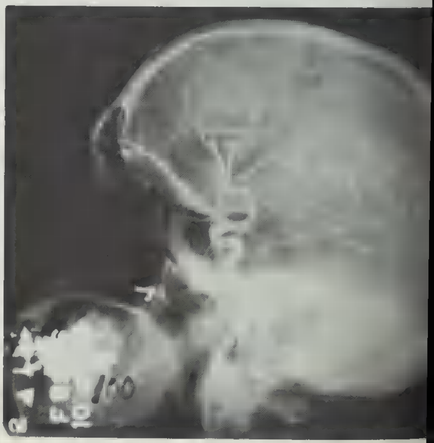


Figure 7.33. Lateral view of skull with opaque me at 100 Kv.P.



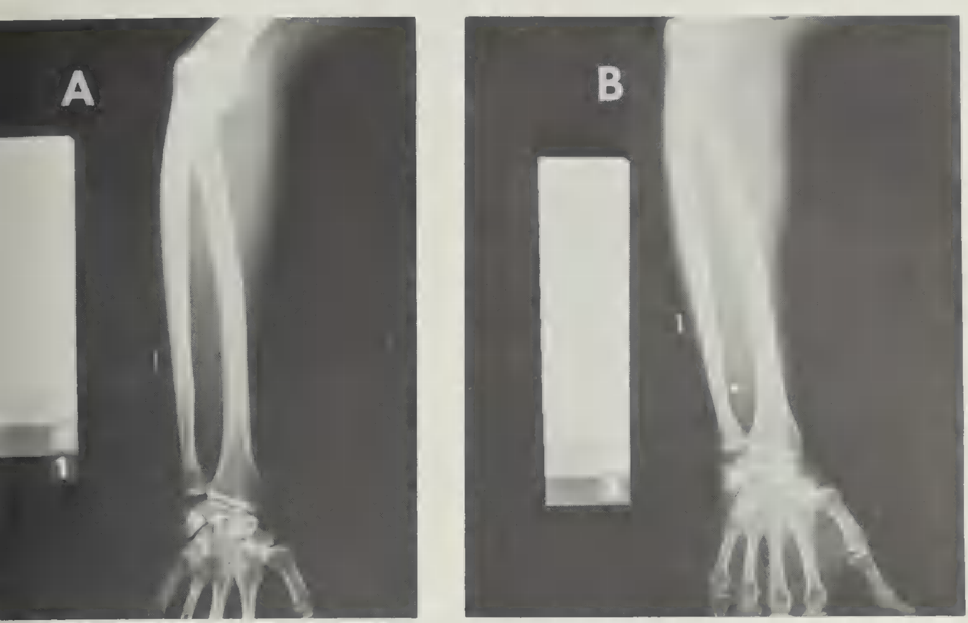
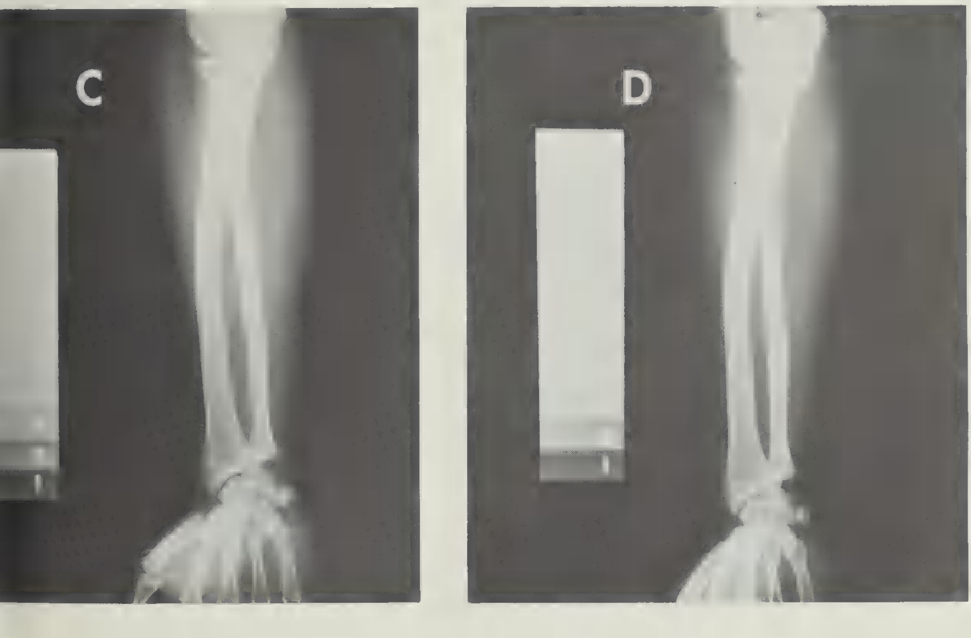


Figure 7.34. Comparison of results. The view in A was taken at 50 Kv.P. and 100 Ma.S. with regular film and a cardboard holder. B was taken at 60 Kv.P. and 70 Ma.S., also with regular film and a cardboard holder. Note the increase in overall detail. Views C and D were taken with regular film and screens – C at 60 Kv. P. and 2.5 Ma.S., and D at 46 Kv.P. and 10 Ma.S.



A fixed kilovoltage technique will produce more uniformity in routine radiography than a relatively low, variable kilovoltage technique since the *latitude* at the higher kilovoltage permits more uniform results.

SECONDARY RADIATION FOG

Secondary radiation fog is a supplement density and obscures image details. Fog is characterized by a dull gray appearance and the absence of contrast and detail. See Figure 7.35.

The amount of secondary radiation fog depends upon *tissue thickness* and *density* of the *subject* matter, as well as the kilovoltage employed.

Secondary radiation fog may be controlled by the proper use of exposure factors, strict coning of the part radiographed, and the use of grids, with a grid ratio appropriate for the thickness and density of the part. It is suggested that the sections on cones, diaphragms, and grids be reviewed in order to become more familiar with the control of secondary radiation fog. Figure 7.36 shows the effect of a cylinder cone in improving contrast by eliminating secondary radiation. Also see Figures 7.16 and 7.17, radiography of the gallbladder.

MILLIAMPERE SECONDS

Milliampere seconds is simply the milliamperage (Ma.) multiplied by the time of exposure in seconds (S.), the product being Ma.S.

It is most important for the technologist to become familiar with Ma.S. since proper control of this factor gives one an opportunity to "fit" the exposure to the problem at hand.

It is suggested that Tables 6.10, 6.11, and 6.12 be referred to in order to become familiar with the most common Ma.S. values used in radiography. The Ma.–Time relation formula on page 132 should be reviewed until one is able to work this formula from memory.

Figure 7.35. Secondary radiation fog.

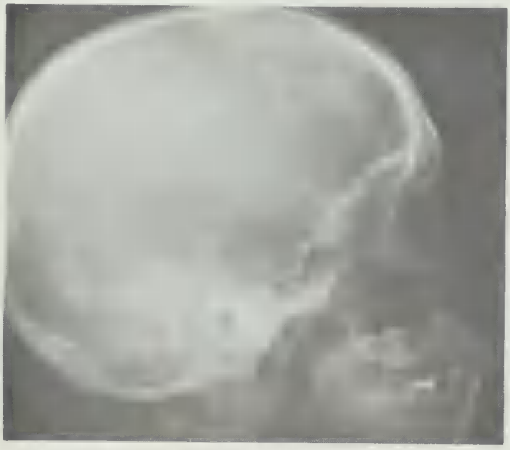
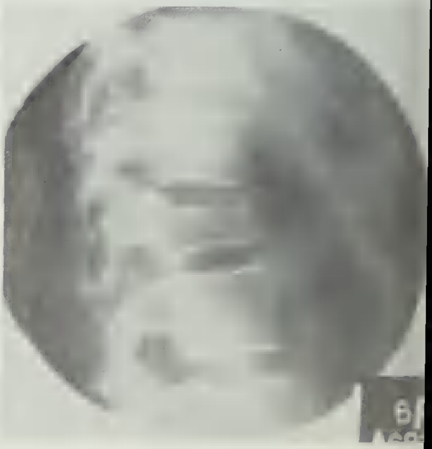


Figure 7.36. In this view, a cylinder cone has b used to reduce secondary radiation.



SUMMARY

PHOTOGRAPHIC ASPECTS

- *I. Radiographic density*
  - Controlled by:
    - Ma.S.
    - Focus-film distance
    - Heel effect
  - Influenced by:
    - Kv.P.
    - Fog
    - Processing
- *II. Radiographic contrast*
  - Controlled by:
    - Kilovoltage
  - Influenced by:
    - Filters
    - Fog (all forms)
    - Development
    - Tissue contrast
    - Type of film
    - Pathology
- *III. Secondary radiation fog*
  - Affected by:
    - Size of area irradiated
    - Compression
    - Cones
    - Diaphragms
    - Grids
    - Kv.P.

GEOMETRIC ASPECTS

- *I. Image sharpness (definition)*
  - Affected by:
    - Focal-spot size
    - Object-film distance
    - Focus-film distance
    - Motion
    - Screen-crystal size
    - Film-screen contact
- *II. Image size (magnification)*
  - Influenced by:
    - Focus-film distance
    - Object-film distance
- *III. Image shape (distortion)*
  - Influenced by:
    - Alignment of tube to film
    - Alignment of part to film
    - Object-film distance

Chapter 8. **FORMULATING THE TECHNIQUE CHART: VARIABLE KILOVOLTAGE METHOD**

Radiography is the art of recording on a sensitive emulsion the hidden structures of the body. The permanent record which we make is called a radiograph. It is a pictorial representation of structures—a form of picture, and like all pictures, it possesses pictorial qualities, namely, *density, contrast, detail,* and *distortion.* Distortion is not thought of as a quality but is always included in this group. We speak of the qualities and we ask, how much density? A satisfactory amount. Satisfactory for whom? The *radiologist.* Contrast? Sufficient. Sufficient for what? *Sufficient to show the anatomical structure.* Detail? How much? *Maximum.* Distortion? *As little as possible.* We might also ask, what is technique? Technique is that combination of mechanical methods by which one achieves a satisfactory balance of these four factors: *density, contrast, detail,* and *distortion.*

Any technique (exposure system) is now, and always has been, subject to patient *evaluation* by the technologist.

All x-ray machines should be calibrated before one attempts to formulate a standard technique chart. Machine factors vary considerably; and, in order to work for a standard production of film quality, one must know the output and characteristics of a particular machine.

The *four primary factors* involved in the production of a radiograph are: *focus-film distance, milliamperage, time of exposure,* and *kilovoltage.* The focus-film distance can be measured accurately and duplicated very easily. Milliamperage can be measured accurately by the milliammeter; the timer can be tested for accuracy by the use of a spinning top for exposures less than one second, and by a stop watch for exposures longer than one second.

Tube-rating chart

Before the technique chart is formulated one should refer to the tube-rating chart since repeated exposures or even *one* long exposure may produce enough heat in the anode to cause serious damage. The tube-rating chart enables one to determine the combination of kilovoltage, milliamperage, and time that can be safely used for any given exposure.

Distance

The distance from the film to the tube focal-spot, known as focus–film distance, is determined to a large extent by the *ratio* and *radius* of the Potter-Bucky diaphragm or grid cassette when used (focused or parallel). The other factor influencing distance is the factor of distortion (short-distance – more distortion; longer distance – less distortion).

Kilovoltage

The kilovoltage should be adequate to penetrate the anatomical part. Kilovoltage governs the *quality* of the x-rays.

Milliamperage

The milliamperage should be high enough to produce a given density. The milliamperage governs the *quantity* or *amount* of radiation.

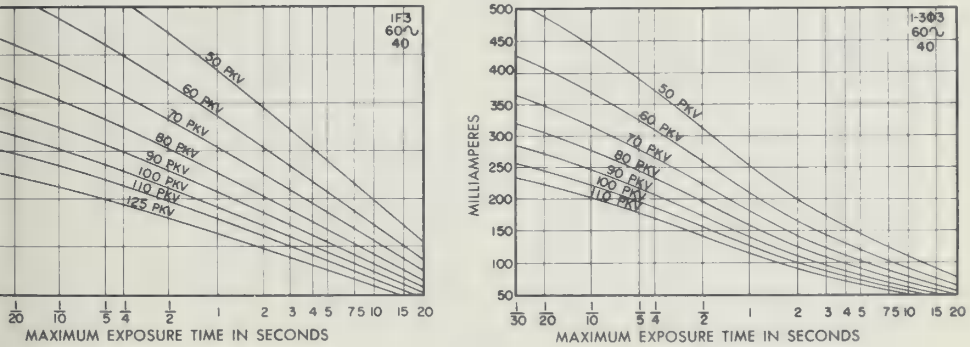
The time factor

The time factor refers to the length of exposure and is usually measured in fractions of a second or in seconds.

Figure 8.1. Tube rating charts – single-phase and three-phase.

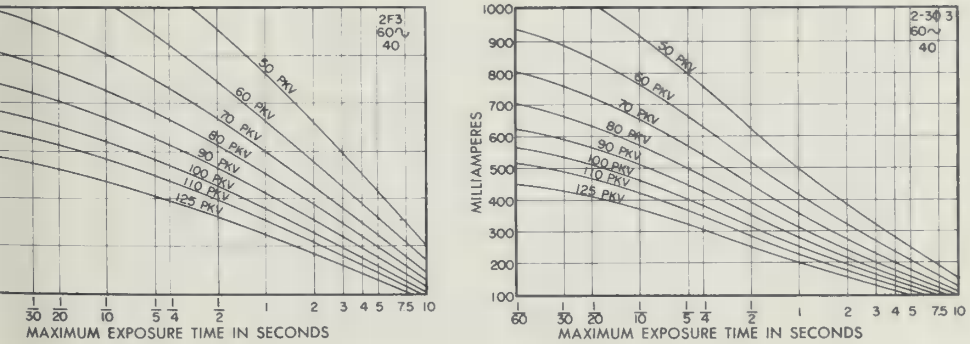
ings For Operation on Full-Wave Rectification
SINGLE PHASE
Small Focal Spot—1.0 mm.

Ratings For Operation on Full-Wave Rectification
THREE PHASE
Small Focal Spot—1.0 mm.



Large Focal Spot—2.0 mm.

Large Focal Spot—2.0 mm.



Milliampere-seconds

Milliampere-seconds (Ma.S.) is a measurement of the milliamperage and time of exposure. Example: 100 Ma. for $1/10$ of a second is 10 Ma.S.; 10 Ma. for 1 second is 10 Ma.S.; 200 Ma. for $1/20$ of a second is 10 Ma.S.

A working knowledge of milliampere-seconds can be a great asset in *fitting* the exposure to the *problem*. (See Tables 6.11 and 6.12 above.)

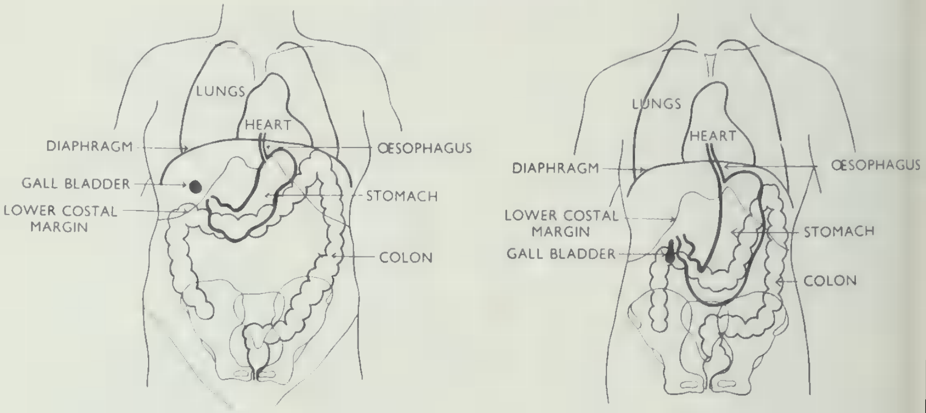
Cones or collimators

A cone or collimator should be used in every projection, in order to reduce secondary radiation fog.

Filters

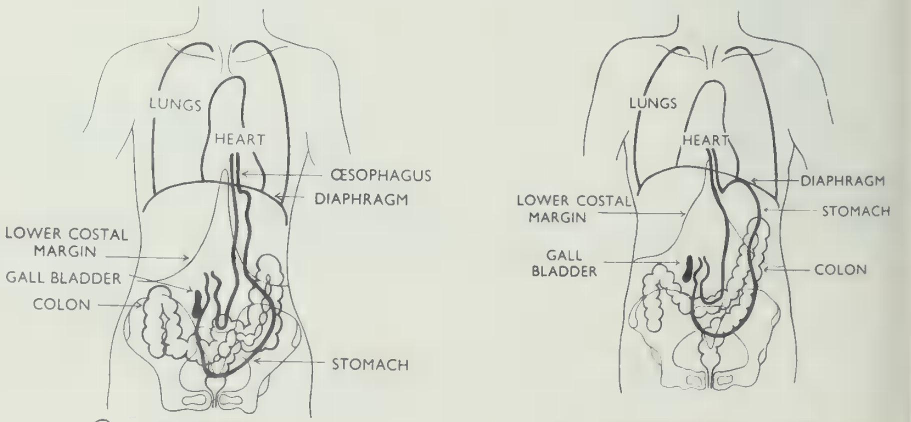
At least 2 mm. of external aluminum filters should be used.

Figure 8.2. Subject types.



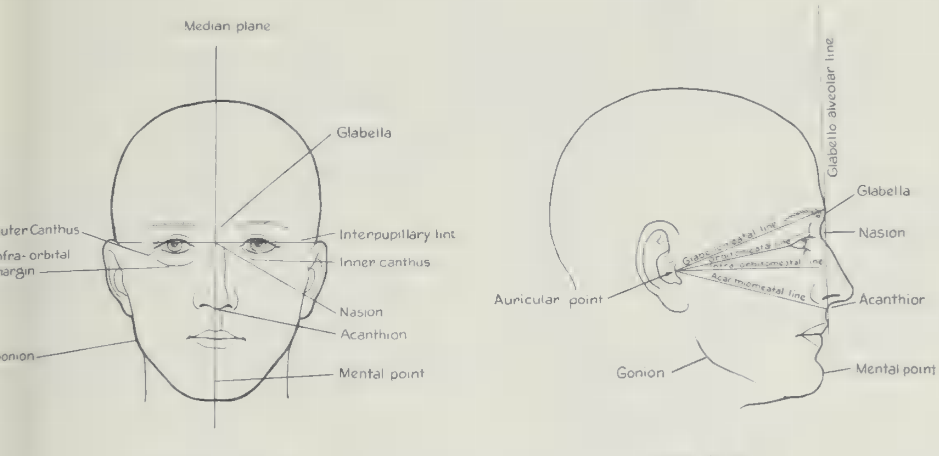
① HYPERSTHENIC 5%

② STHENIC 48%



③ ASTHENIC 12%

④ HYPOSTHENIC 35%



ANTERIOR ASPECT

LATERAL ASPECT

Figure 8.3. Basic localization points and planes.

The Potter-Bucky diaphragm and grids

With few exceptions the Bucky or a grid should be used for radiography of all parts 12 centimeters or more in thickness. Exceptions are the lungs, heart (except for large, heavy patients), lateral mandible, hands, wrists, ankles, legs, and sinuses.

Screens or cardboard holders

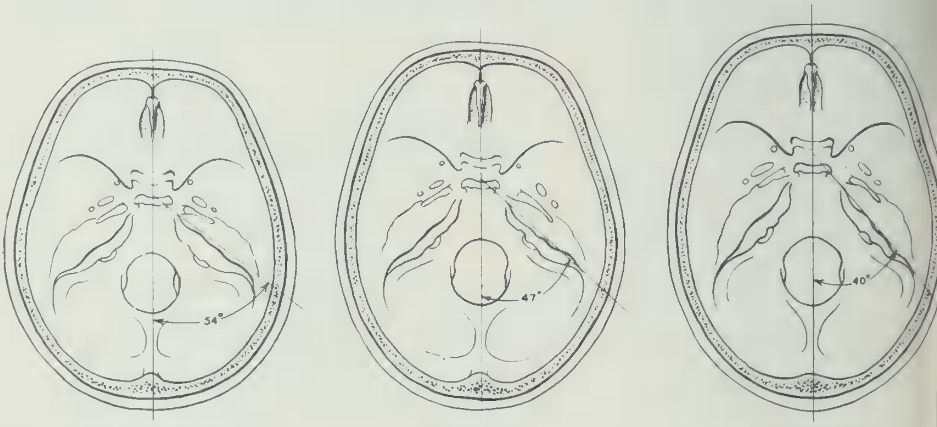
Screens should be used where speed is important and for all parts other than the so-called *small parts,* e.g., extremities and nasal bones, except in certain special techniques.

THE PATIENT PROBLEM

When the patient is ready for the radiograph the physical characteristics and region or part to be examined should be carefully observed. Any information regarding the pathology or condition of the region, or regions, to be examined will usually prove helpful, and the time for which the part can be held in a comfortable, steady position should be noted.

Experience will enable the radiologic technologist to judge by the physique of the patient the proper location of the organs, especially those of the abdomen, and particularly the gallbladder, stomach, and colon. The technologist should understand the four distinct subject types of body habitus: namely, hypersthenic, sthenic, asthenic, and hyposthenic; and in skull radiography he should understand the three types of skulls: namely, brachycephalic, dolichocephalic, and mesocephalic. Atypical skulls will, depending upon their shape, require more or less rotation of the head, or an increase or decrease in the angulation of the central ray. In the brachycephalic skull, which is short from front to back, broad from side to side, and shallow from vertex to base, the internal structures are higher with reference to the base line and the long axis is more frontal in position. In the dolichocephalic skull, which is long from front to back, narrow from side to side, and deep from vertex to base, the internal structures are lower with reference to the base line and the long axis is less frontal in position. Asymmetry of one's skull should also be considered, but if the technologist will adhere to the fundamental radiographic base lines and rules of positioning, he will encounter little difficulty. Care and precision should always be used, and the use of a protractor or cardboard angles will be tremendously advantageous in producing standardized results. The mesocephalic, or so-called normal, skull is more or less oval in shape, being wider behind than in front. The average skull measures approximately 15 centimeters in the lateral position, 19 centimeters in the anteroposterior position, and 22 centimeters in the mentovertex position. Skulls vary in size and shape with both sex and race, resulting in a variation in the position and relationship of internal parts. Internal deviations from the normal are usually indicated by the external deviations, so that they can be estimated with a reasonable degree of accuracy. There is a 4-centimeter difference between the lateral and anteroposterior measurements of the normally shaped skull. Any deviation from this relationship indicates a change in relationship of the internal structures which, if more than a 5° change, must be compensated for by either a change in rotation of the part, or the angulation of the central ray.

Figure 8.4. The three types of skulls.

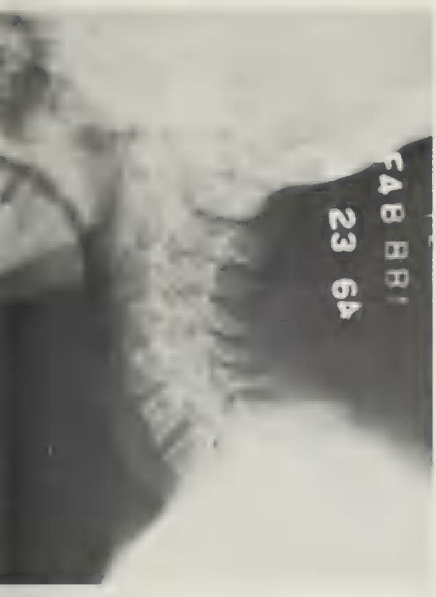


Brachycephalic Mesocephalic Dolichocephalic

Positioning and measuring

Proper positioning of the patient guarantees that definite anatomical structures will be projected into the active radiographic field while proper measuring of these structures determines the necessary x-ray energies to be selected to allow the best diagnostic evaluation. *Duplicate diagnostic densities are possible only when all technologists position and measure the anatomical structure under consideration in the same manner.*

Generally speaking, the measurement in centimeter depth for any particular structure is along the line of centrally projected radiation. The part to be radiographed should always be measured by calipers. Do not simply measure to cassette or table top; do not make the mistake of computing the measurement of an A.P. lumbar spine by measuring depth to table top when the spine does not rest on the table.



8.5 Radiograph of the cervical spine showing
pper positioning of the patient.

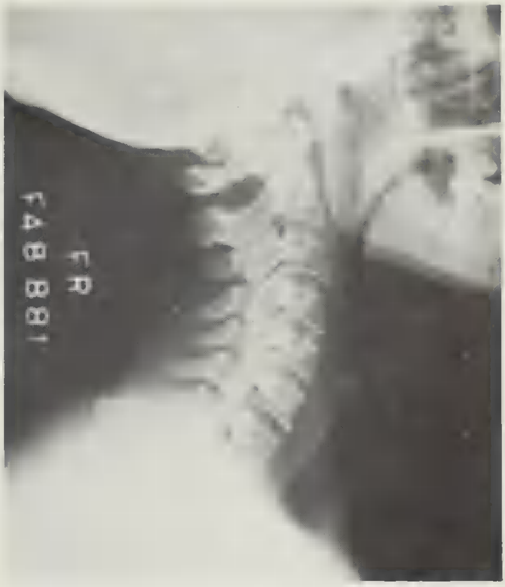


Figure 8.6. The patient of Figure 8.5 in correct position.

Sometimes certain anatomical structures present a variable contour, which may be the case in certain P.A. chest radiography. In such patients, an average between the normal measurement and that of the deepest part to be projected into the active field must be considered.

In other instances like the A.P. lumbar, the measurement is indicated at a point $2\frac{1}{2}$ inches below the sternum or the lower margin of the anterior ribs while the central ray is localized over the umbilicus. These exceptions must be carefully studied in order to guarantee satisfactory end results.

The application of compression bands may cause a considerable change in thickness of the part to be radiographed. Measurements should be made after the patient has been placed in position for the exposure.

Classification of tissue

By classification of tissue, we refer to the relative radiolucency of different types of tissue—such as for emaciation, superfluous flesh, muscle, and normal flesh. In bone radiography, atrophy from age, disuse, or disease must be considered. In examinations of the thorax the type of patient, age, amount and consistency of tissue, and amount of air in the lungs are determined by the structural type of the individual.

To compensate for tissue differences in the small, medium, and large patient, one may use classifications of A-B-C. "A" would represent the thin and emaciated patient, "B" the normal or medium patient, and "C" the large or muscular patient. For A, B, and C classifications, milliampere-seconds values are given; for example, in the lateral radiography of the three types for lumbar spine, each measuring the same thickness, "A" would require less milliampere seconds and "C" would require more milliampere seconds than the "B" type patient. It is apparent that if the same peak kilovoltage and the same milliampere seconds were given all three patients, the "A" type patient's radiograph would be overexposed while the "C" type patient's would be underexposed.

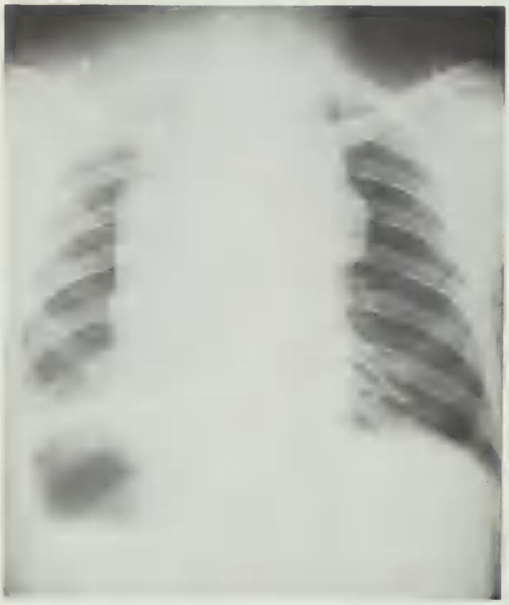


Figure 8.7. Chest with Hodgkin's disease, given normal exposure.

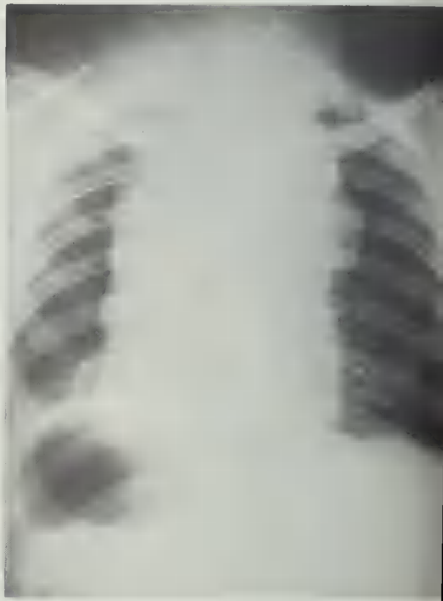
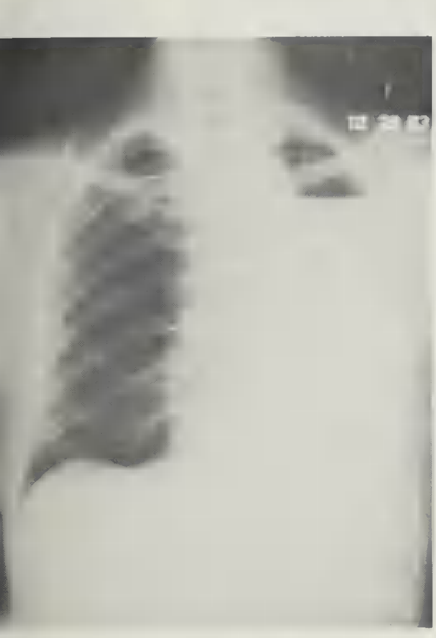


Figure 8.8. The chest of Figure 8.7, with the co
tion of an added 5 Kv.P.

Thickness of part

A variation in thickness of extremities should not cause a great deal of difficulty; it is easier to compensate for variations here than in working with the heavier parts. If the object being radiographed is an ankle swollen to the size of the average knee, then the knee technique should be used; if the individual is of such size that the normal ankle is the size of the average knee, the same thing holds true. The radiologic technologist with limited experience should spend considerable time in studying the thicknesses of the part which is being radiographed; with added experience his errors due to poor judgment of the thickness of the subject will, of course, be reduced. Variations in thicknesses and size of the pelvis, kidney, lumbar spine, etc., are much more difficult to judge even for the experienced technologist. When a lack of uniformity exists in the routine radiographs produced in the department, it is usually with the heavier parts of the body. When the subject to be taken is unusually large, there is a tendency on the part of the technologist to use too much penetration.

A film which is too light in radiographic density, but which has received full development, or a film too dark in radiographic density after full development, at once tells the radiologic technologist that the energy used has been either insufficient or too much. In either case it is relatively simple either to increase or to decrease the energy for the next radiograph. The experience gained from such a procedure will be far more valuable when the next heavy patient is to be radiographed than the experience gained from employing too much energy and from improper processing.



e 8.9. Chest with fluid, given normal exposure.

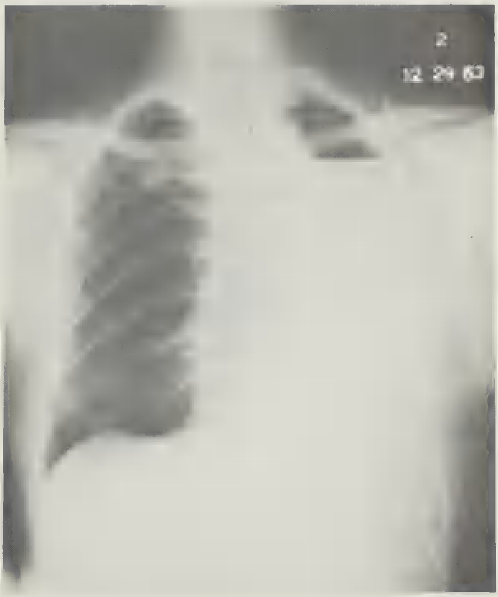


Figure 8.10. The chest of Figure 8.9, with the correction of an added 5 Kv.P.

It *must* be realized by every technologist, however, that the thickness of any body part is not an index of its physiology or its x-ray absorption qualities, and cannot be employed *per se* as an authoritative index of the radiographic density desired to be produced.

THE CHEST

The chest is less dense to x-rays than any other part of the body of the same thickness. The soft tissues and bones of the thoracic wall are like similar structures elsewhere, but air in the lungs reduces the average density to a marked degree.

Children and infants

The chests of adults of different thicknesses are of approximately the same radiographic density. If a given thickness of the thorax of a child, however, is compared to a similar thickness of the thorax of an adult, the average density to x-rays of that of the child is considerably greater than that of the adult. This is most marked in infants and gradually decreases as age advances.

This greater opacity makes necessary a special exposure technique for films of the chest of infants and children.

Types of thoracic cavities

Radiography of the thoracic cavity and lungs requires more attention and care than that of any other body group. Results will depend largely upon classification of patients into proper groups. There are several types of patients, and the judgment of the technologist is of great importance.

Heavy chest type. This class represents a type of individual having a heavy, dense muscular frame and normally assumes a plus percentage correction factor depending upon tissue density. Women with very heavy frame and very large breasts should be placed in this group.

Thin chest type. Such patients are generally recognized when they are properly positioned against the cassette changer with their shoulders and arms thrown forward, because of protruding scapulae and lack of flesh. A minus percentage correction factor is necessary. (Some average patients of normal build will be found with scapulae extending beyond the normal measure.)

Very thin type. This individual is the barrel-chested type with below normal flesh, generally having good expansion, where the thoracic cavity repre-

Figure 8.11. Plus 30 per cent correction factor for Paget's disease.

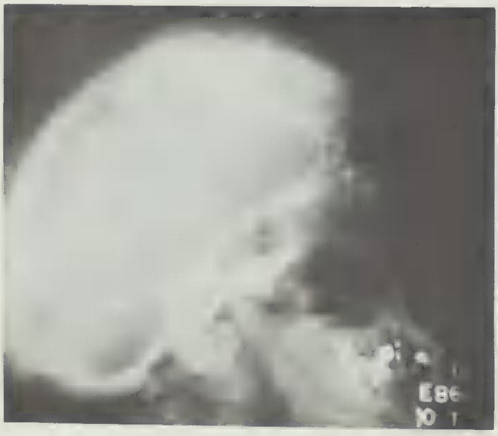
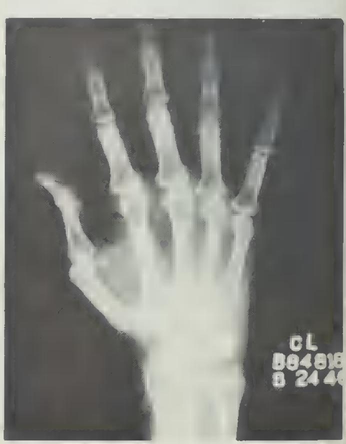


Figure 8.12. Plus 30 per cent correction factor for acromegaly.



sents practically the entire depth of the thorax. Such patients need a reduction in energy, generally through the manipulation of Ma.S. to a point considerably below that proper for a normal chest.

Pathology. The technologist should obtain specific information from the request slip in respect to suspected pathology so as to be able to apply positive percentage correction factors.

THE PATHOLOGICAL FACTOR

Pathology may exist with any or all parts to be radiographed; therefore, too much emphasis cannot be placed on the technologist's ability to classify or evaluate pathological conditions that require an increase or decrease in exposure from the normal. Patients cannot be classified by thickness alone.

Table 8.1 CORRECTIVE FACTORS

Easy to penetrate	*Suggested correction for use with variable kilovoltage technique*
Age: 60 years and up	Less 30%Ma.S.
Arthritis	Minus 5 Kv.P.
Atrophy	Less 30% Ma.S.
Children	See age correction table, Table 6.7
Cystic diseases	Less 30% Ma.S.
Emphysema	Minus 5 Kv.P.
Hydrocephalus (with air study)	Less 30% Ma.S.
Hyperparathyroidism	Less 30% Ma.S.
Infants	See age correction table, Table 6.7
Metastasis	Less 30% Ma.S.
Multiple myeloma	Less 30% Ma.S.
Osteoporosis	Less 30% Ma.S.
Pneumothorax	Minus 5 Kv.P.
Sarcoma	Less 30% Ma.S.
Gout	Less 30% Ma.S.
Hard to penetrate	*Suggested correction for use with variable kilovoltage technique*
Acromegaly	Plus 30% Ma. S.
Advanced tuberculosis (chest)	Plus 5 Kv.P.
Blastomycosis (chest)	Plus 5 Kv.P.
Cancer (lung)	Plus 5 Kv.P.
Edema	Plus 30% Ma.S.
Empyema	Plus 5 Kv.P.
Fluid (chest)	Plus 5 to 8 Kv.P.
Fluid (abdomen)	Plus 8 to 10 Kv.P.
Hodgkin's disease (chest)	Plus 5 to 8 Kv.P.
Hydropneumothorax	Plus 5 Kv.P.
Hydrocephalus (without air)	Plus 30% Ma.S.
Lung abscess	Plus 5 Kv.P.
Muscular subject	Plus 30% Ma.S.
Paget's disease	Plus 30% Ma.S.
Pleural effusion	Plus 5 Kv.P.
Pneumonia	Plus 5 Kv.P.

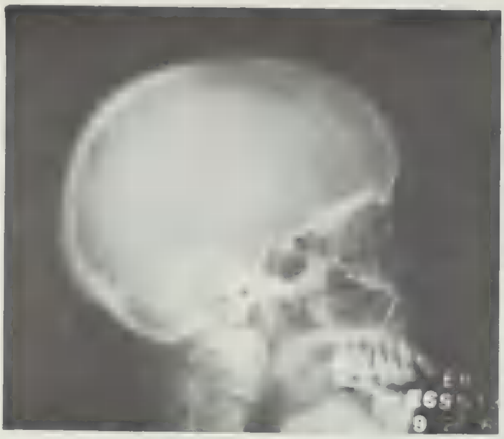


Figure 8.13. Lateral view of skull with hyperparathyroidism, with normal exposure.

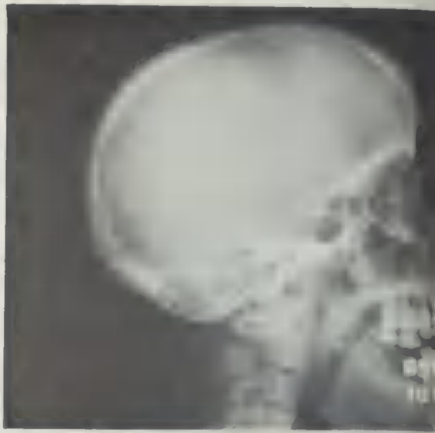


Figure 8.14. The skull of Figure 8.13, with a min per cent correction in Ma.S.

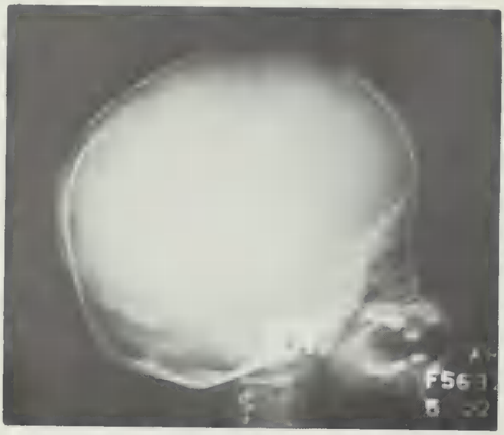


Figure 8.15. Lateral skull with hydrocephalus: plus 30 per cent correction in Ma.S.

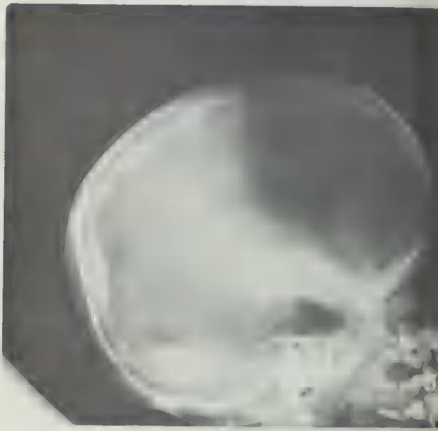


Figure 8.16. The skull of Fig. 8.15, with a minu per cent Ma.S. correction for hydrocephalus an *air study* on the same patient.

Figure 8.17. P.A. view of hands with a minus 30 per cent correction in Ma.S. for gout.

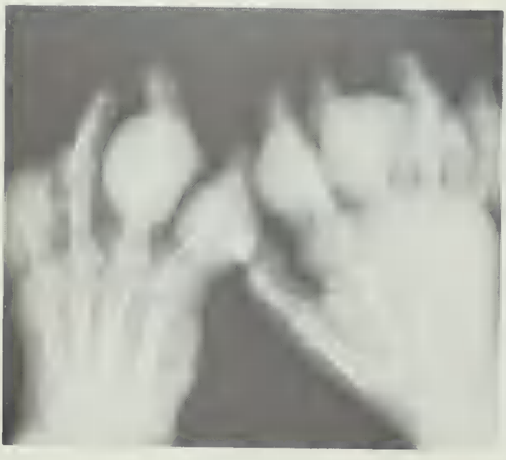
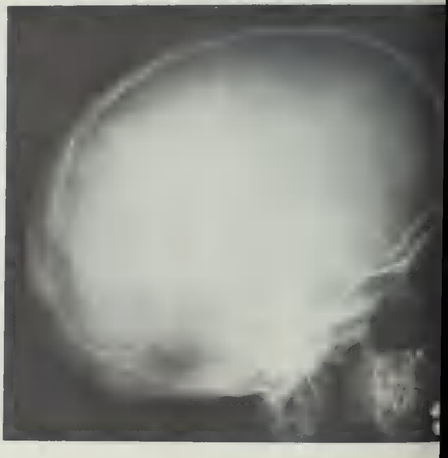


Figure 8.18. Lateral skull of a child with hydroce lus with a plus 30 per cent correction factor.



VARIABLE KILOVOLTAGE TECHNIQUE CHART

Select an individual of average size and start with any group of parts of similar density.

The lateral skull will be used as our starting point. Measure the subject in the lateral projection. On the average, this measurement will be 15 centimeters. *Multiply the centimeter thickness by 2 and add the figure 30 to the product.* In this manner we arrive at the figure 60, which is known as our *base kilovoltage.* In other words, a 15 centimeter lateral skull would require 60 Kv.P.; a 16 centimeter skull would require 62 Kv.P.; a 14 centimeter skull would require 58 Kv.P.

Select the *milliampere-seconds* thought to be most appropriate for this group.

Select the focus-film distance and a cone which will restrict radiation to the part.

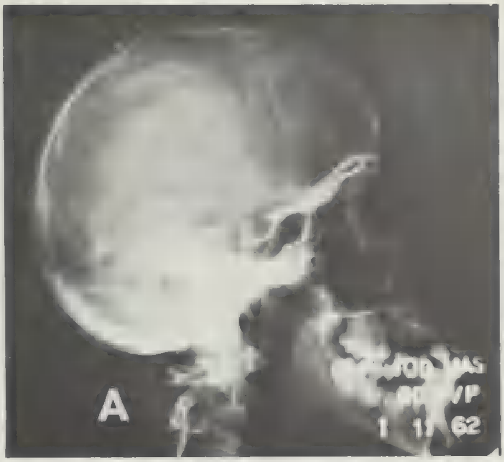
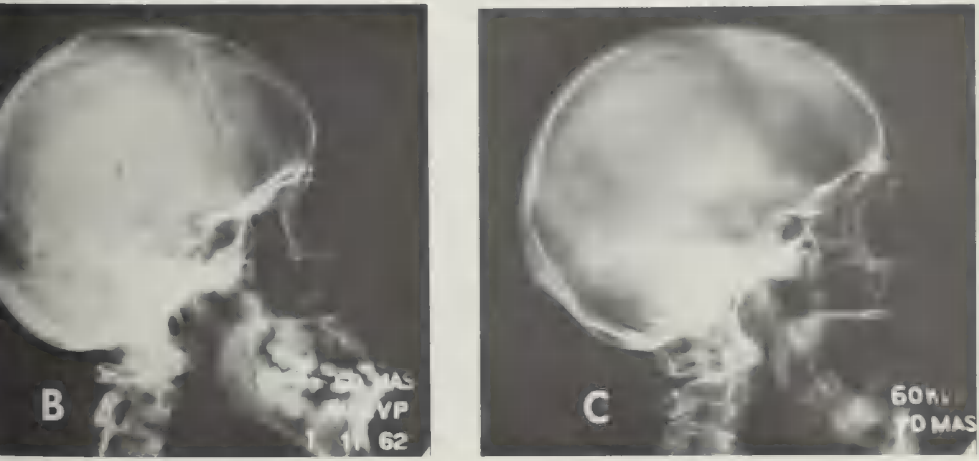


Figure 8.19. Lateral views of a skull. A shows the initial film, an overexposure. In B the Ma.S. was reduced to half to compensate, and the result is an underexposure. In C the Ma.S. was adjusted to give a correct exposure by using the average Ma.S. for the two previous Ma.S. values.



The technical factors we will use, then, are:

Focus–film distance	36 inches
Bucky	8-to-1 ratio
Cm.	15
Kv.P.	60
Ma.S.	100
Cone	To part

Place the subject in the lateral skull position and make an exposure employing the above factors. Develop the film according to *standard time-temperature* or *automatic* processing; inspect under standard illumination. If the film is overexposed (see Figure 8.19A) reduct the Ma.S. by one-half and repeat (see Figure 8.19B). If this film is underexposed, repeat, going in between 100 and 50 Ma.S. and use 70 or 75 Ma.S. (see Figure 8.19C).

If this meets our standards we now have a working technique as follows:

Region: Skull
Position: Lateral
Cone: V-10
Ma.: 100

Time: $^7/_{10}$
Ma.S.: 70
Dist.: 36
Bucky: Yes

Cm.:	13	14	15	16	17	18	19	20	21	22	23
Kv.:	56	58	60	62	64	66	68	70	72	74	76

These factors will hold for the entire skull group. See the following figures: 8.20, P.A. skull; 8.21, lateral view of mastoid with a cylinder cone *but* at a 30-inch focus–film distance; 8.22, Stenvers at 30 inches; 8.23, optic foramen

Figure 8.20. P.A. view of skull.

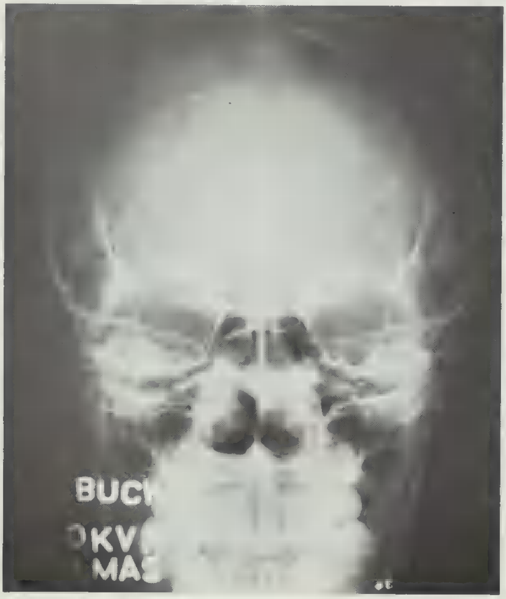
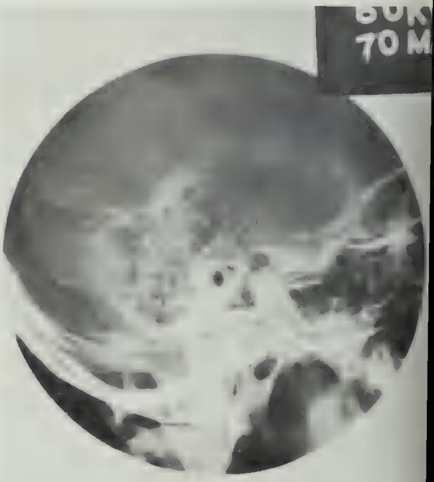


Figure 8.21. Lateral view of mastoid with cyli
cone at 30-inch focus-film distance.



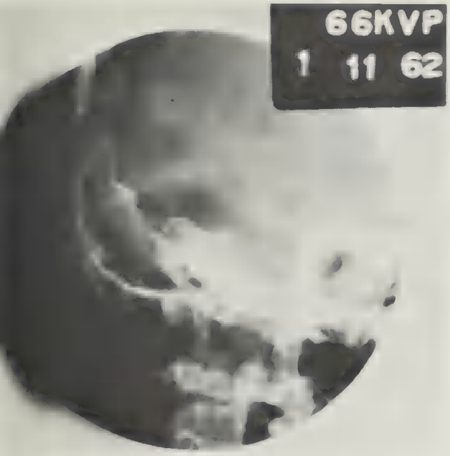


Figure 8.22. Stenvers at 30 inches.

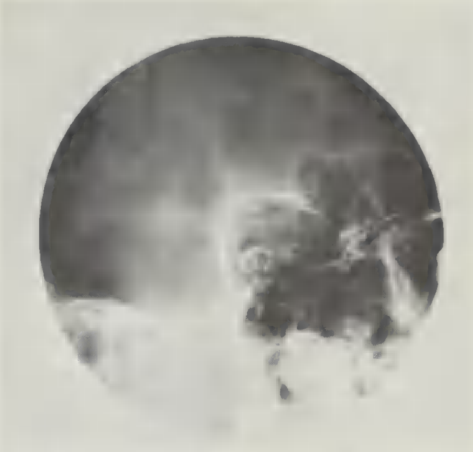
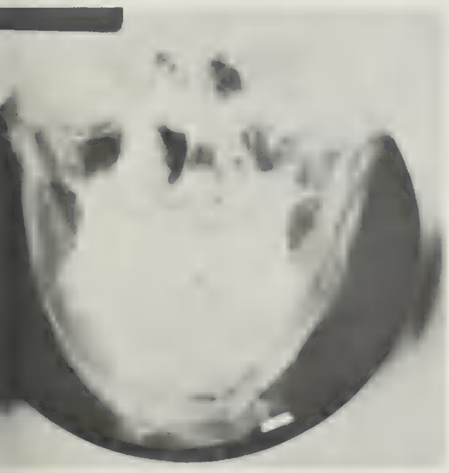


Figure 8.23. Optic foramen at 30 inches.



igure 8.24. P.A. view of mandible at 30 inches.

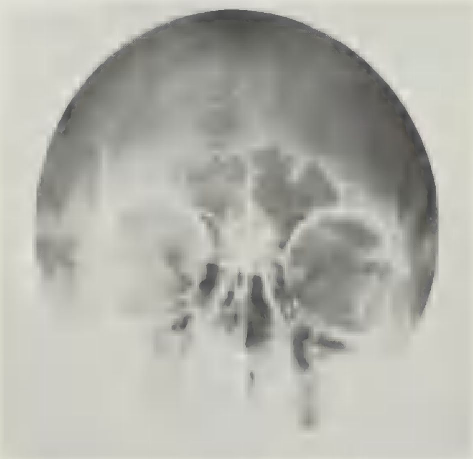


Figure 8.25. Caldwell at 30 inches, using Bucky.

ure 8.26. Child's skull, with reduction in Ma.S. ording to Table 6.7.

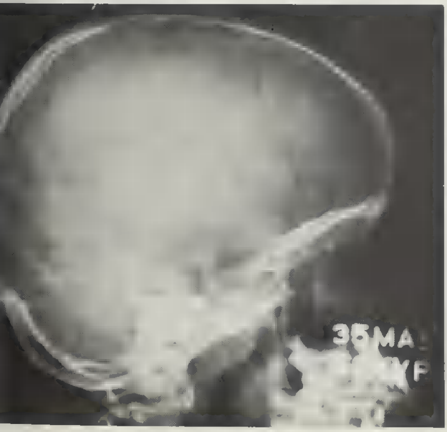
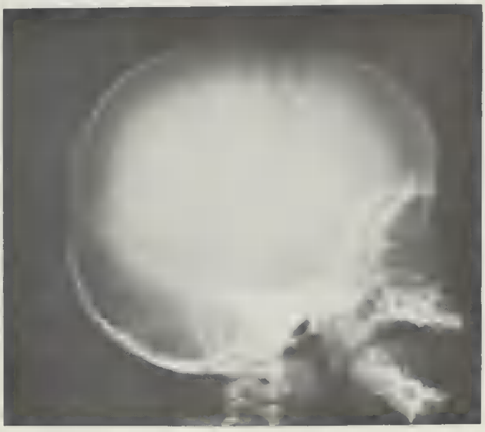


Figure 8.27. Infant's skull, with reduction in Ma.S according to Table 6.7.



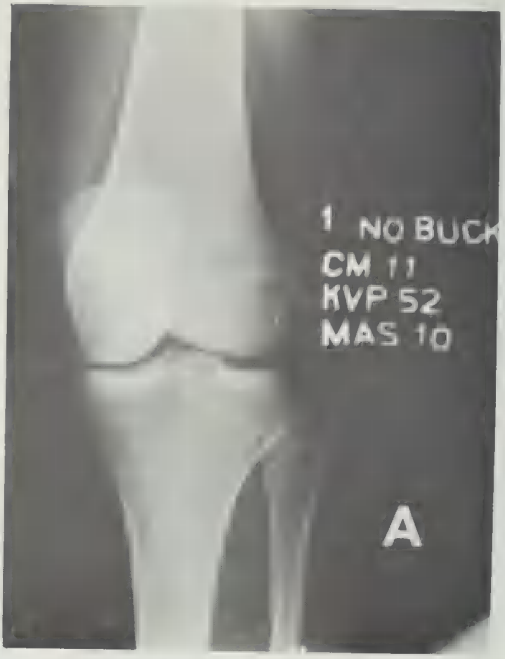
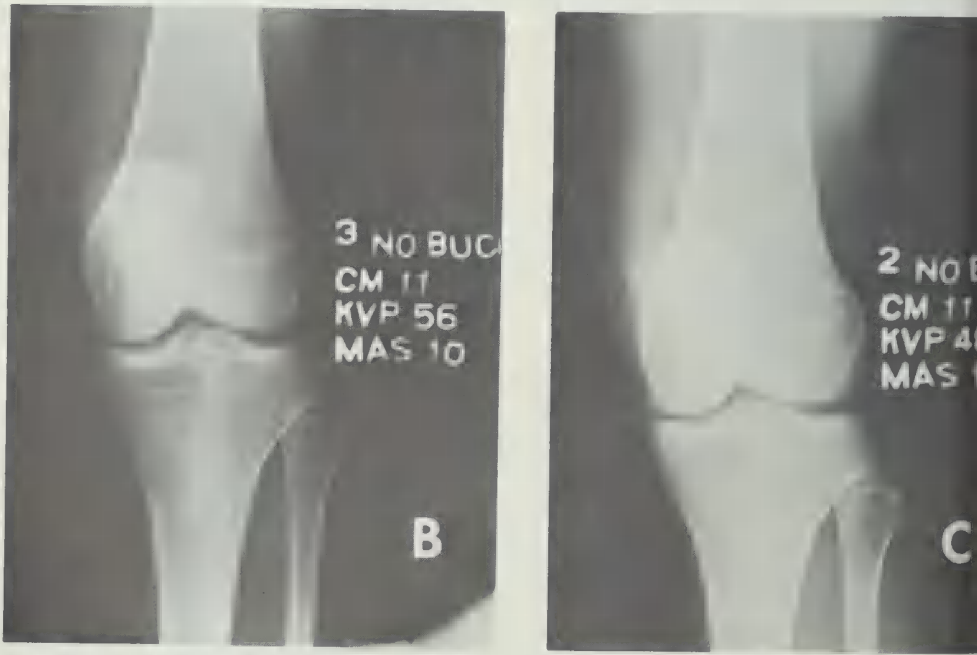


Figure 8.28. Three radiographs of the knee, all at 10 Ma.S. View A is taken at 52 Kv.P., B at 56 Kv.P., and C at 48 Kv.P.



at 30 inches; 8.24, P.A. mandible at 30 inches; 8.25, Caldwell at 30 inches, using Bucky.

Also Figure 8.26, a child's skull with a reduction in Ma.S. according to the age correction table, page 128, and Figure 8-27, an infant's skull, also with a reduction in the Ma.S. according to the age correction table.

The above procedure is followed throughout the entire chart for *each group* of parts of *similar density.*

The next step is to apply our Ma.S. correction factors for the adult patients who are above or below normal. This correction is based on a 30 per cent change in Ma.S. In other words, we would add 30 per cent to our base or normal Ma.S. for patients who are above normal, and decrease our Ma.S. by 30 per cent for patients who are below normal.

A-type patient: 40 Ma.S.
B-type patient: 70 Ma.S. (normal)
C-type patient: 100 Ma.S.

For infants and children, with the *exception* of the *chest,* we can use the age correction table to obtain the correct Ma.S. and then simply measure the part and use the Kv.P. as listed under the Cm.-Kv.P. scale. A possible exception to this would be the lateral thoracic and lumbar spine.

For uncooperative patients, simply convert the Ma.S. to a higher Ma. value and a faster time. See Table 6.12 or use the time-milliamperage formula below. Example: change a 2-second exposure at 50 Ma. to $\frac{1}{2}$ second.

$M_1:M_2 :: T_2:T_1$
$50:x :: \frac{1}{2}:2$
$\frac{1}{2}x = 100$
$x = 200$ = new Ma. for $\frac{1}{2}$ second

Extremity group

Let us select the knee to start this group. Select the Ma.S. you want to use. In this case we want to use 10 Ma.S. We have a choice:

100 Ma. at $\frac{1}{10}$ second = 10 Ma.S.
200 Ma. at $\frac{1}{20}$ second = 10 Ma.S.
300 Ma. at $\frac{1}{30}$ second = 10 Ma.S.

Since the 100 Ma. station is on the small focus, let us select 100 Ma. at $\frac{1}{10}$ of a second, a 36 inch focus–film distance and par speed screens.

Measure the knee in the A.P. projection and add the figure 30. In this case the knee measures 11 cm.; therefore 2 x 11 = 22, 22 + 30 = 52. This is our base Kv.P.

To save time, let us expose the knee at 52 Kv.P. (Figure 8.28A), another exposure at 4 Kv.P. less (Figure 8.28B), and another exposure at 4 Kv.P. above (Figure 8.28C).

All three films should be developed at standard time-temperature processing and then placed on the illuminator for evaluation. Suppose we select film number 1 (see Figure 8.28A). We now can insert 52 Kv.P. under 11 cm. on our scale.

If we wish to obtain more contrast and better detail we can go to a Bucky technique. We have a choice in how we make our compensation. For high contrast we can *treble* the Ma.S., which would be 30 Ma.S. All other factors remain the same (see Figure 8.29). Or if we wish to have better penetration and a reasonable amount of contrast, we *add* 20 Kv.P. and use 72 Kv.P. (see Figure 8.30). All other factors remain the same.

Let us select an Ma.S. factor that does not work out on the first exposure.

Example: It is desired to formulate the extremity technique. Let us select the lateral foot and ankle.

Cm.: 7
Kv.P.: 44
Dist.: 36 inches
Ma.: 100
Time: $^1/_{20}$
Ma.S.: 5

Cone: To film
Film: Regular
Screens: Medium
Development: 5 minutes at 68°
Bucky: No

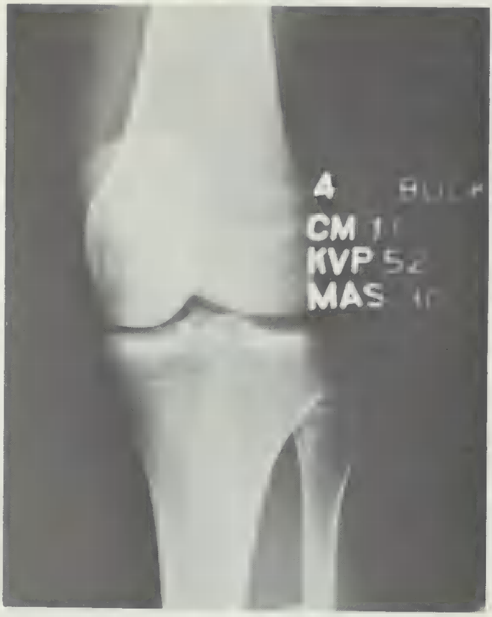


Figure 8.29. Knee with Bucky at 30 Ma.S.

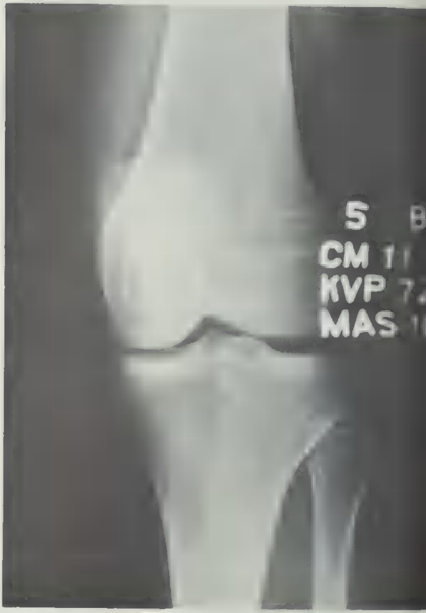


Figure 8.30. Knee with Bucky at 72 Kv.P.

Expose the part using the above factors (see Figure 8.31). Upon inspection of the finished radiograph we find we have penetrated the part but have insufficient density. Expose a second film with an increase in Ma.S., since Ma.S. is the controlling factor for density. The second radiograph exposed at 10 Ma.S. (see Figure 8.32) is of the desired quality. We then would have:

Cm.: 7
Kv.P.: 44
Dist.: 36 inches
Ma.: 100
Time: second
Ma.S.: 10

Cone: To film
Film: Regular
Screens: Medium
Development: 5 minutes at 68°
Bucky: No

By adding 2 Kv.P. per centimeter thickness to the base kilovoltage of 30, our extermity chart would be:

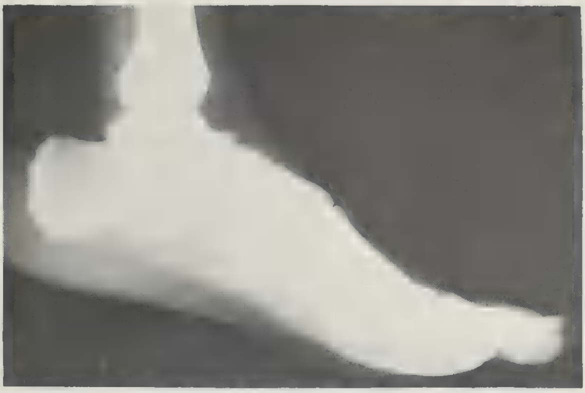


Figure 8.31. Lateral view of foot and ankle at 5 Ma.S.

Ma.: 100 *Time:* $^{1}/_{10}$ *Distance:* 36" *Screens* *Bucky:* No. *Cone:* To Part

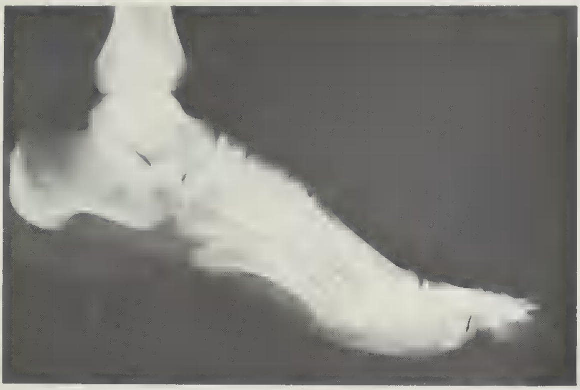
Cm.	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Kv.	34	36	38	40	42	44	46	48	50	52	54	56	58	60

To compensate for children and infants, we would use the age correction table, p. 128. A typical technique chart formulated for all parts by this method is shown on pages 184–85.

RADIOGRAPHIC GUIDE: VARIABLE KILOVOLTAGE TECHNIQUE

It might seem rather difficult to follow charts with stated factors since it is commonly known that all machines will vary to a certain extent. It must be understood that the purpose of any chart in this book is to serve as a guide so that when one part has been satisfactorily adapted to existing conditions, all other parts of the same group will require the same corrections.

Figure 8.32. Lateral view as in Figure 8.31, at 10 Ma.S.



Cone——Videx
C-Cone——Cylinder
Film——Regular
Screens——Medium
Bucky——8-to-1
Tube——Rotating Anode
Development – 5 minutes at 68°

Age Correction Factor

Age	*Factor*
Birth to 3 months	.2
3 months to 2 years	.3
2 years to 5 years	.4
5 years to 7 years	.5
7 years to 12 years	.6

(See page 128)

Region	*Position*	*Cone*	*Ma.*	*Time*	*Ma.S.*	*Distance*	*Bucky*
Skull	Lateral	V-10	100	7/10	70	36	yes
	A.P.-P.A.	V-8	100	1	100	36	yes
	Vertex	V-8	100	1	100	36	yes
	Petrous-A.P.	C	100	1 1/4	125	36	yes
	Optic	C	100	8/10	80	33	yes
	Stenvers	C	100	8/10	80	33	yes
	Mastoid-Lat.	C	100	7/10	70	30	yes
	Waters	V-8	100	1	100	36	yes
	Mandible-P.A.	C	100	1	100	33	yes

Ma.S.
A – minus 30%
B – normal
C – plus 30%

Cm.	10	11	12	13	14	15	16	17	18	19	20	21	22
K.V.	50	52	54	56	58	60	62	64	66	68	70	72	74

Facial Bones	Mandible-Lat.	C	100	1/10	10	33	no
	Nasal-Lat.	C	100	1/20	5	30	no
	T.M.J. A.P.	C	100	1/10	10	30	no
	Maxilla P.A.	C	100	2/5	40	33	no
	Zygomatic	C	100	1/10	10	33	no

Cm.	3	4	5	6	7	8	9	10	11	12
K.V.	34	36	38	40	42	44	46	48	50	52

Sinuses	Lateral	C	100	1/10	10	30	no
	Frontal	C	100	2/5	40	33	no
	Maxillary	C	100	2/5	40	33	no
	Sphenoid	C	100	2/5	40	33	no
	Lateral	C	100	3/10	30	33	yes
	P.A.	C	100	1 1/4	125	33	yes

Cm.	10	11	12	13	14	15	16	17	18	19	20	21	22
K.V.	48	50	52	54	56	58	60	62	64	66	68	70	72

Ma.S.
A – minus 30%
B – normal
C – plus 30%

Shoulder	A.P.	V-8	100	1/4	25	36	yes
Scapula	A.P. & Lat.	V-10	100	1/4	25	36	yes
Humerus	A.P. & Lat.	V-10	100	1/5	20	36	yes

Cm.	8	9	10	11	12	13	14	15	16	17	18
K.V.	54	56	58	60	62	64	66	68	70	72	74

The Technique Chart: Variable Kilovoltage

on	*Position*	*Cone*	*Ma.*	*Time*	*Ma.S.*	*Dis-tance*	*Bucky*
l	A.P.	V-8	100	1	100	36	yes
l	Spot-C-1	C	100	1	100	30	yes
	A.P.	V-14	100	1	100	36	yes
-	A.P.	V-11	100	1	100	36	yes
-	Obl.	V-8	100	1	100	36	yes
	A.P.	V-14	100	1	100	36	yes
	A.P.	V-14	100	1	100	36	yes
dder	P.A.	C	100	1	100	36	yes

Ma.S.
A – minus 30%
B – normal
C – plus 30%

Cm.	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
K.V.	52	54	56	58	60	62	64	66	68	70	72	74	76	78	80	82

Ma.S.
A – minus 30%
B – normal
C – plus 30%

nities	All	To part	100	1/10	10	36	no
nities	All	To part	100	1/2	50	36	non-screen
nities	All	To part	100	3/10	30	36	Bucky

Cm.	2	3	4	5	6	7	8	9	10	11	12	13	14
K.V.	34	36	38	40	42	44	46	48	50	52	54	56	58

Ma.S.
A – minus 30%
B – normal
C – plus 30%

Stomach and Colon

P.A. – Oblique – Lateral   Ma: 200   Distance: 36   Bucky: yes

Cm.:	15	16	17			C.M.:	18	19	20	21	22
K.V.	86	88	90			K.V.:	82	84	86	88	90
Time:	1/10					Time:	1/5				
Cm.:	23	24	25	26	27	C.M.:	28	29	30	31	
K.V.:	82	84	86	[illegible]	90	K.V.:	86	88	90	92	
Time:	2/5					Time:	1/2				

n	*Position*	*Cone*	*Ma.*	*Time*	*Ma.S.*	*Dis-tance*	*Bucky*
	P.A.	V-14	300	1/30	10	72	no
	Oblique	V-14	300	1/15	20	72	no
	Lateral	V-14	300	1/15	20	72	no

Cm.	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
K.V.	62	64	66	68	70	72	74	76	78	80	82	84	86	88	90

Special Lateral Exposure

on	*Position*	*Cone*	*Ma.*	*Time*	*Ma.S.*	*Dis-tance*	*Bucky*
	Lateral	V-8	300	1/15	20	72	no
al	Oblique	V-8	300	1/15	20	72	no

Ma.S.
A – minus 30%
B – normal
C – plus 30%

Cm.	8	9	10	11	12	13	14	15	16
K.V.	68	70	72	74	76	78	80	82	84

Ma.S.
A – minus 30%
B – normal
C – plus 30%

r	Lateral	V-11	50	4	200	36	yes
	Lateral	C	50	7	350	33	yes
etry	Lateral	V-14	50	5	250	36	yes

Cm.	21	22	23	24	25	26	27	28	29	30	31	32	33	34
K.V.	72	74	76	78	80	82	84	86	88	90	92	94	96	98

A – minus 30%
B – normal
C – plus 30%

Thoracic	Lateral	V-14	25	6	150	36	yes

Cm	21	22	23	24	25	26	27	28	29	30	31	32	33	34
K.V.	48	50	52	54	56	58	60	62	64	66	68	70	72	74

RADIOGRAPHIC GUIDE

Department of Radiology Duke University Medical Center Durham, North Carolina

Region	*Position*	*Cone*	*Ma.*	*Time*	*Ma.S.*	*Dist.*	*B.*	*Film*
Skull	Lateral	10	100	7/10	70	36	√	10/12
	P.A.	8	100	1	100	36	√	8/10
	A.P.	8	100	1	100	36	√	8/10
	Mentovertex	8	100	1	100	36	√	8/10
	Occipital	8	100	1	100	36	√	8/10
	Stenvers	C	100	8/10	80	30	√	8/10
	Petrous	C	100	1 1/4	125	36	√	8/10
	Mastoid	C	100	7/10	70	30	√	8/10
	Waters	8	100	1	100	36	√	8/10
	Optic	C	100	8/10	80	30	√	8/10
	Mandible, Lat.	C	100	1/10	10	30	No	8/10
	Nasal Bones	C	100	1/20	5	30	No	8/10
Spine	Cervical, A.P.	8	50	2	100	36	√	8/10
	Cervical, Lat.	8	300	2/15	40	72	No	8/10
	Cervical, Obl.	8	300	2/15	40	72	No	8/10
	Dorsal, A.P.	7	100	1	100	36	√	7/17
	Dorsal, Obl.	11	100	1	100	36	√	11/14
xxx	Dorsal, Lat.			see below				
	Lumbar, A.P.	11	100	1	100	36	√	11/14
	Lumbar, Obl.	8	100	1	100	36	√	8/10
	Lumbar, Lat.	11	100	2	200	36	√	11/14
	Lumbar, Spot-L-5	C	50	5	250	30	√	8/10
	Pelvis, A.P.	14	100	1	100	36	√	14/17
Shoulder	A.P.	8	100	1/2	50	36	√	8/10
	Axial	8	100	1/10	10	36	No	8/10
Sternum	P.A. Obl.	11	100	1	100	36	√	11/14
	Lateral							
Gallbladder	P.A.	8	100	4/5	80	36	√	8/10
	Decubitus	8	100	4/5	80	36	√	8/10
	Upright	8	100	4/5	80	36	√	8/10

Cm.	*Kv.P.*
2	34
3	36
4	38
5	40
6	42
7	44
[illegible]	46
9	48
10	50
11	52
12	54
13	56
14	58
15	60
16	62
17	64
18	66
19	68
20	70
21	72
22	74
23	76
24	78
25	80
26	82
27	84
28	86
29	88
30	90
31	92

The Technique Chart: Variable Kilovoltage

Region	Position	Cone	Ma.	Time	Ma.S.	Dist.	B.	Film
Abdomen	A.P.	14	100	4/5	80	36	√	14/17
	Decubitus	14	100	4/5	80	36	√	14/17
K. U. B.	Upright	14	100	1	100	36	√	14/17
	Lateral	14	100	1	100	36	√	14/17
Extremities	Screen	8	100	1/10	10	36	No	8/10
	No Screen	8	200	1/4	50	36	No	8/10
	Bucky	8	100	3/10	30	36	No	8/10
	Infant	8	100	1/20	5	36	No	8/10

Cm.	Kv.P.
32	94
33	96
34	98

Region	Position	Cone	Ma.	Time	Ma.S.	Dist.	B.	Film
Pelvimetry	Thoms, A.P.	10	200	1	200	36	√	10/12
	Lateral	14	50	4	200	36	√	14/17
	Placenta	See below: use barium filter						
Ribs	A.D.	14	50	1/5	10	36	√	14/17
	B.D.	14	100	3/5	60	36	√	14/17

Position	Cone	Ma.	Time	Ma.S.	Dist.	Bucky
Sinuses, Lat.	C	100	1/10	10	30	No
Frontal	C	100	2/5	40	30	No
Maxillary	C	100	2/5	40	30	No
Sphenoid	C	100	2/5	40	30	No

Cm.	12	13	14	15	16	17	18	19	20	21	22	23	24
Kv.	52	54	56	58	60	62	64	66	68	70	72	74	76

	Cone	Ma.	Time	Ma.S.	Dist.
Chest, P.A.	14	300	1/30	10	72
Chest, Oblique	14	300	1/15	20	72
Chest, Lateral	14	300	1/15	20	72
Chest, P.A., Grid	14	Add	20	Kv.P.	72
Chest Obl., Grid	14	Add	20	Kv.P.	72
Chest Lat., Grid	14	Add	20	Kv.P.	72

Cm.	17	18	19	20	21	22	23	24	25
Kv.	60	64	64	66	68	70	72	74	76

Cm.	26	27	28	29	30	31	32		
Kv	78	80	82	84	86	88	90		

	Cone	*Ma.*	*Dist.*	*Bucky*	*Film*
Stomach P. A., Obl.	10	200	36	\	10/12
Stomach Serial	10	200	30	\	10/12
Stomach Spot Film	Use	photo	timer		8/10

Cm.	15	16	17		18	19	20	21	22			23	24	25	26	27	28	29	30	31
Kv.	86	88	90		82	84	86	88	90			82	84	86	88	90	86	88	90	92
Time	1/10					1/5							2/5					1/2		

Note: This type chart is formulated by 2 times the part plus 30. The Ma.S. has been corrected for each group except the chest. The chest, as well as the lateral thoracic spine, has a Kv.P.–Ma.S. balance.

AGE CORRECTION FACTORS**

Use Adult Kv.P. Scale, multiply Ma.S. by Factor

Age	*Factor*
Birth to 3 Months	0.2
3 Months to 2 Years	0.3
2 Years to 5 Years	0.4
5 Years to 7 Years	0.5
7 Years to 12 Years	0.6

**Not to be used for children's or infant's chests.

SPECIAL EXPOSURE

Lateral Dorsal Spine

MA: 50 Time: 3 sec. Dist: 36″ Bucky: yes

CM:	23	24	25	26	27	28	29	30	31	32	33
KV:	52	54	56	58	60	62	64	66	68	70	72

Infant Chest

MA: 50 Time: 1/20 Dist.: 36″ Bucky: no

CM:	8	9	10	11	12	13	14	15
KV:	44	46	48	50	52	54	56	58

Oblique: add 6 Kv.P.
Lateral: add 10 Kv.P.

Child's Chest

MA: 300 Time: 1/20 Dist: 72″ Bucky: no

CM:	12	13	14	15	16	17	18
KV:	54	56	58	60	62	64	66

Oblique: add 6 Kv.P.
Lateral: add 10 Kv.P.

Placenta — Lateral

300 Ma.S. 36″ Dist.
Small: 60 Kv.P. Medium 65 Kv.P.
Large: 70 Kv.P.

The Technique Chart: Variable Kilovoltage

The Kardex type technique chart (variable kilovoltage) is shown below.

Part: Skull					*Position: Lateral*		
Remarks:							
Ma.	*Time*	*Dist.*	*Bucky*	*Cone*	*Film*	*Screen*	*Cardboard*
100	$^{7}/_{10}$	36	yes	V-10	10 × 12	par	no

Cm.	13	14	15	16	17	18
Kv.	56	58	60	62	64	66

CLOSE SUBJECT–TUBE DISTANCE TECHNIQUE

Under certain conditions a short subject–tube distance, i.e., focal spot 25 to 30 inches from the subject being radiographed, will be of value.

The short distance takes advantage of the wide divergence of the x-rays. The close position of the tube or focal spot causes blurring of the superimposed parts distant from the film, while the part to be radiographed, being in close contact with the film, still remains sharply outlined. This technique can be used in radiography of the sternum in the P.A. oblique position, the temporomandibular joint, and differentiation of gallstones and kidney stones. See Table 6.3 for distance change.

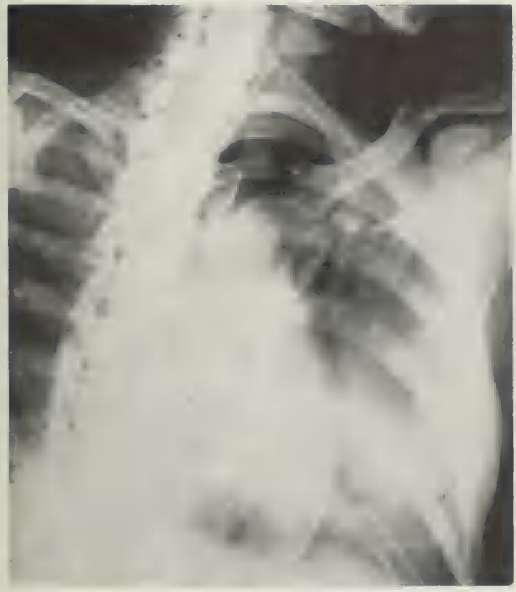


Figure 8.33. Close subject-tube distance technique: P.A. view of a sternum at 50 Ma.S. and 65 Kv.P.; distance 30 inches, cone to part, 8-to-1 grid, medium screens.

EXPOSURE NOMOGRAMS FOR POLAROID TLX FILMS

Directions for use: Figures 8.34 and 8.35 are nomograms based on original experimentation done at The Duke University Medical Center and at the Polaroid Corporation. These nomograms may be used with any regular or medium speed film.

Take a clear plastic ruler and place on the kilovoltage you are now using for routine radiography. Connect this line with the Ma.S. you are now using for wet processing. Where the line connects with the Polaroid Ma.S. is the new Ma.S. to be used with the Polaroid TLX film.

Example: With regular film and high speed screens ■ technique calls for 60 Kv.P. and 100 Ma.S. Following the above directions we would use 30 to 33 Ma.S. with Polaroid TLX film.

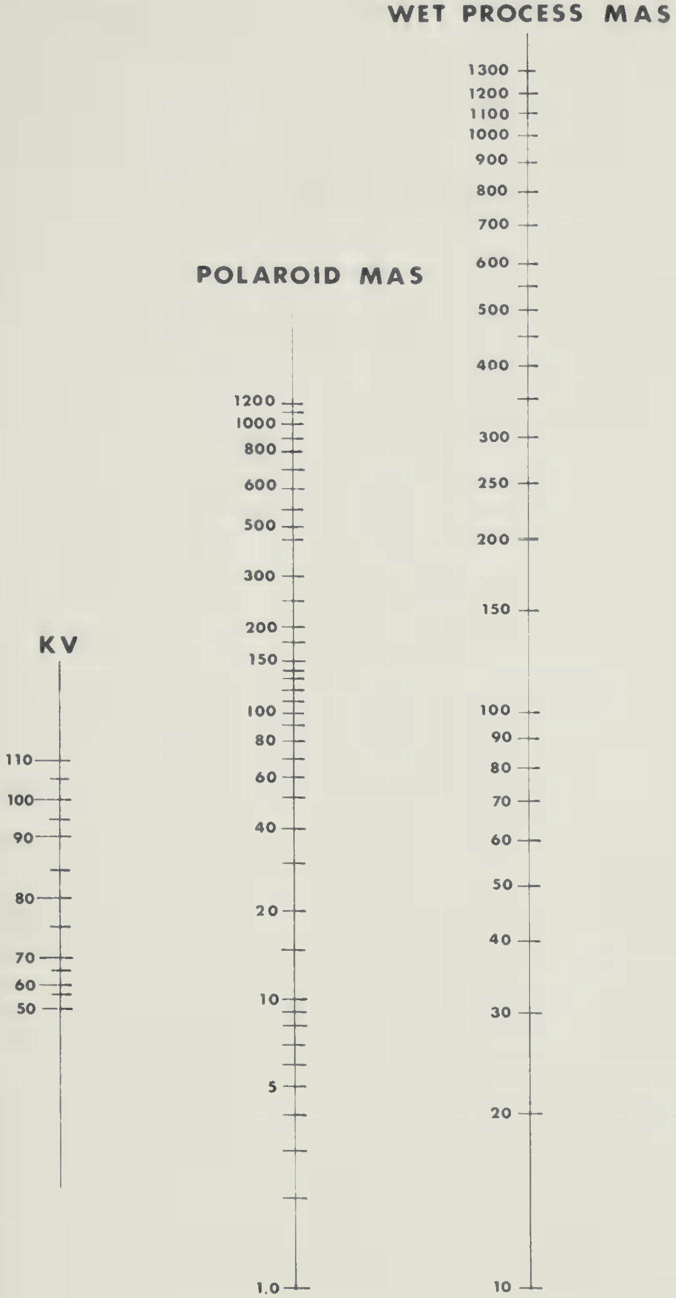


Figure 8.34. Nomogram relating Polaroid TLX exposures to techniques developed for regular film and *high-speed screens*.

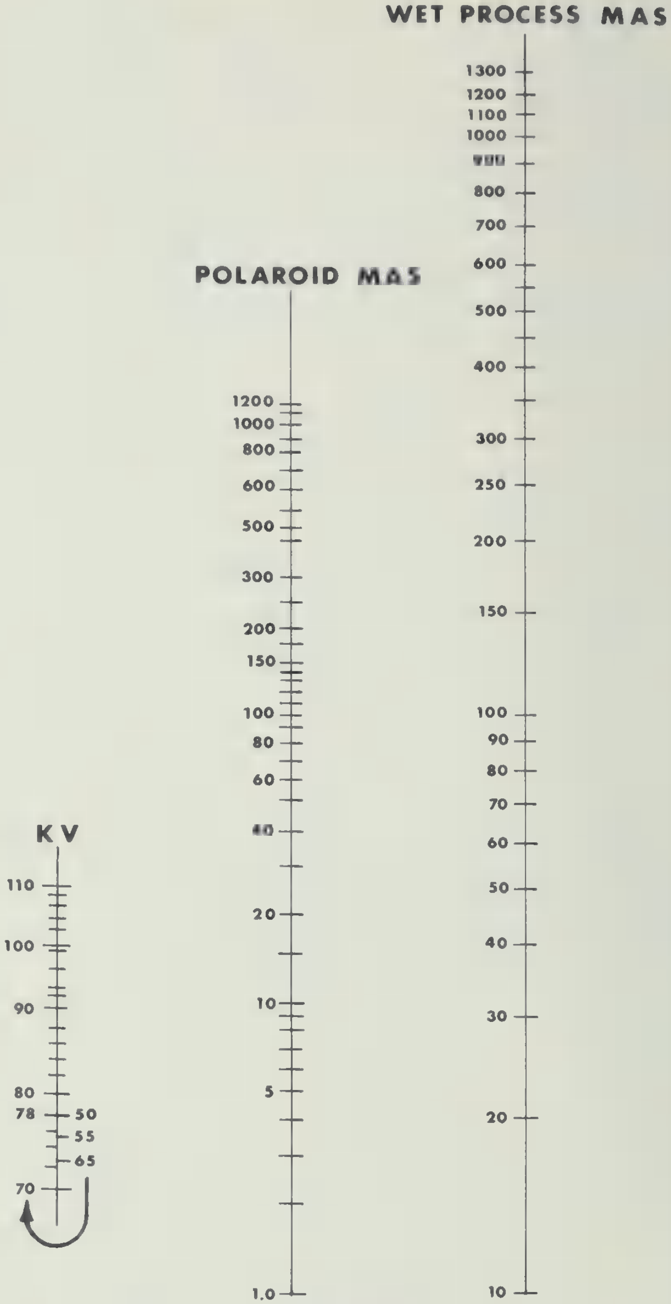


Figure 8.35. Nomogram relating Polaroid TLX exposures to techniques developed for regular film and *par-speed screens*.

Chapter 9. **THE FIXED KILOVOLTAGE SYSTEM OF TECHNIQUE**

Present-day radiography requires standardization of apparatus and technique in order that all operations performed may entail a minimum of time and yield results of the best quality.

The results of the beginning student in radiography, whether good or poor, are usually unintelligible to him. For that reason he must early become acquainted with the kind of radiograph that is most useful to the radiologist—one that possesses correct diagnostic quality. The student cannot acquire that knowledge except by actually making such radiographs under careful guidance. His familiarity with satisfactory radiographs, based on experience in making them, instills in him a self-confidence that is of immeasurable value in the field of radiography.

To facilitate this training, there is a simple yet exact exposure system—the fixed kilovoltage technique—developed by the late Arthur W. Fuchs, which requires little applicatory effort on the part of the student and instructor. Wherever practical, the exposure factors are reduced to constants, thereby eliminating many possible sources of error. This system enables the student to quickly become acquainted with radiographs of better than average quality that are produced in the course of instruction. It precludes floundering about, seeking exposure factors for making a particular radiograph the quality of which he is often incapable of judging in the early stages of training. The fact that the fixed kilovoltage system requires the elimination of nonessentials or variables from the technical procedure accounts for the success of the technique, since it provides a clear-cut method of procedures, assures the technologist of better than average results, and is easily understood and applied by the beginner as well as the experienced radiologic technologists.

The fixed kilovoltage system does not require actual measurement of the body parts. With some experience, the technologist *learns to estimate* the thickness and is able to classify the part as *small, average,* or *large.* Since the average classification predominates, he may successfully place about 90 per cent of all patients in this category. The basic constants of kilovoltage and milliampere seconds are so few in number that they are easily memorized, and for ready reference, the factors may be placed on a small card (see Figure 9.1).

The employment of the fixed kilvoltage technique will consistently produce radiographs of good quality with a minimum of effort. Since the method is standardized, shifting of personnel from one room to another should not

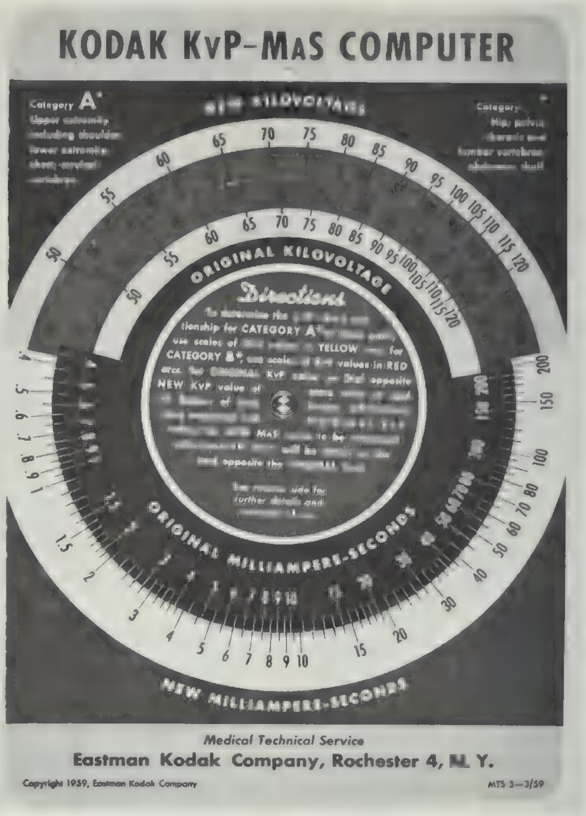

KODAK KvP-MaS COMPUTER
Category A
NEW KILOVOLTAGE
Category
ORIGINAL KILOVOLTAGE
Directions
ORIGINAL MILLIAMPERE-SECONDS
NEW MILLIAMPERE-SECONDS
Medical Technical Service
Eastman Kodak Company, Rochester 4, N. Y.
Copyright 1959, Eastman Kodak Company
MTS 3—3/59

Figure 9.1. Kodak KvP-MaS Computer.

interfere with the uniformity of results; each technologist trained in it should produce a radiograph of the same quality and type as his predecessor. The radiographic densities produced by this method are uniform—a point of considerable diagnostic value because any differences from the normal density may be attributed to pathological changes within the tissues. Duplication of results is easy to obtain in follow-up cases.

The tendency in present-day radiography has been to use high milliamperages to perform work which they are not always capable of performing. It must be understood that for a given thickness of a particular body part, the wave lengths of the x-rays employed to penetrate the tissues must be adequate. Since the kilovoltage governs the *wave length* and *penetration*, all that is then necessary to secure a satisfactory image is to have a sufficient number of x-rays reach the film. The milliamperage and time control the *number* of x-rays or *intensity* of radiation, and proper adjustment of these factors will produce adequate exposure of the radiographic film. When the x-ray wave length is correct, a lesser amount of milliampere seconds is usually needed for the exposure that is habitually employed for the same purpose with lower kilovoltages. This is most important where conservation of tube life is necessary, for it is the milliampere seconds that commonly destroy tubes—not kilovoltage. Less milliampere seconds will permit a greater number of radiographs to be made over a given area before the limit of radiation safety is reached.

In determining a fixed kilovoltage system of technique a premise has been established as to the diagnostic acceptability of the image. The image should be as near 100 per cent acceptable as possible. The scale of contrast should be such that all anatomical details are readily visible. This, of course, depends upon the penetration. Each part should be adequately penetrated. Only a minimum of secondary radiation fog should be tolerated. The average density level should be such that the majority of densities are translucent when the standard type of illuminator is used.

The determination of fixed kilovoltage for various projections involved quite a bit of preliminary experimentation with subsequent testing.

1. A series of exposures were made of a particular part employing a given projection. The radiographs were made at various kilovoltages, usually 40 to 100, in 10-Kv.P. steps. At first, a number of values were employed, but later the kilovoltages were narrowed to three of four for trial. The Ma.S. value used with each Kv.P. was adjusted so that the average over-all densities of the radiographs were approximately the same. The densities for the same anatomical area were balanced for each radiograph.

When it was determined that a given Kv.P. would be adequate, it was tried on a large number of patients using a single basic Ma.S. value. In some instances the radiographic densities were adjusted to suit the average range of tissue densities. As soon as the radiographs assumed a measure of uniformity, the Kv.P. and basic Ma.S. factors were established as constants.

2. Measurements of tissue for a given projection were carefully made. Calipers were employed and skin-to-skin measurements were made without compression of tissues. When these measurements were obtained, correlation with anthropometric data was secured so that frequency and reliability of the measurements could be assured.

The frequency of measurement to establish the average thickness ranges were computed and established as shown in Table 9.1. The kilovoltage was established to suit the nature of radiography to be done—whether screen, direct exposure, or screen-grid exposures—and the greater frequencies were then tested radiographically, using the kilovoltage selected as optimum for the projection.

When measurements were encountered that were greater or less than average, some adjustment in the Ma.S. was necessary. However, the kilovoltage was to remain constant. Borderline thickness ranges were established. In some instances, compensation could be made by halving the Ma.S. with those parts measuring less than the average and doubling the Ma.S. for those parts greater than the average. This could usually be done where the per cent frequency was very high, as with the P.A. view of the hand.

As the per cent frequency of thickness became lower, refinements in the thickness divisions had to be made. Considering the basic Ma.S. as x, then the halfway point between it and $2x$ would be $1\frac{1}{2}x$. Also, with x and $\frac{1}{2}x$, the halfway point would be $\frac{3}{4}x$.

For example, if 80 Kv.P. was initially established for the chest projection (P.A.) with a basic Ma.S. of 3.3 at 72 inches using screens, then these factors were used on 82 per cent of all adult patients entering the department

Table 9.1 PROJECTION AND RANGES OF AVERAGE THICKNESS–ADULT

Region	*Average thickness adult—cms.*			*Per cent frequency* 1	*Kv.P.* 2
	A.P.	*P.A.*	*Lat.*		
Thumb, Fingers, Toes	1.5–4			99	50
Hand	3–5			99	
			7–10	93	
Wrist	3–6			99	
			5–8	98	
Forearm	6–8			94	60
			7–9	92	
Elbow	6–8			96	
			7–9	87	
Arm (S)	7–10			95	
			7–10	94	
Shoulder (S)	12–16			79	
Clavicle (S)		13–17		82	
Foot	6–8			92	
			7–9	91	
Ankle	8–10			86	
			6–9	96	
Leg (S)	10–12			85	65
			9–11	89	
Knee (S)	10–13			92	
			9–12	92	
Thigh (S + PB)	14–17			77	75
			13–16	76	

Region		Average thickness adult—cms.			Per cent frequency 1	Kv.P. 2
		A.P.	P.A.	Lat.		
Hip	(S + PB)	17–21			76	
Cervical Vertebrae	(S) C1-3	12–14			77	65
	(S) C4-7	11–14			98	
	(S) C1-7			10–13	90	85
Thoracic Vertebrae	(S + PB)	20–24			76	75
				28–32	81	85
Lumbar Vertebrae	(S + PB)	18–22			69	70
				27–32	77	85
Pelvis	(S + PB)	19–23			78	70
Skull	(S + PB)		18–21		96	85
				14–17	88	
Sinuses (S)	Frontal		18–21		97	70
	Maxillary		18–22		88	
				13–17	96	
Mandible	(S)			10–12	82	
Chest	(S)		20–25		82	80
		Obl.		27–32	84	90
		24–30			83	85

(1) Per cent frequency of average thickness in various projections, and (2) required kilovoltages that assume complete penetration. (It is assumed that when needed average-speed screens (S) and 8 to 1 PB diaphragm (PB) are used).

and measuring 20 to 25 centimeters. Cases measuring 25 to 29 centimeters were exposed with $2x$ Ma.S.; those measuring 16 to 20 were exposed with $\frac{1}{2}x$ Ma.S. These figures were later revised so that for a 21- to 24-centimeter range, x Ma.S. was used; $1\frac{1}{2}x$ Ma.S. was used for 24 to 27 centimeters; and $2x$ was used for 27 to 30 centimeters. For the 18 to 21 group, $\frac{3}{4}x$ was used, and $\frac{1}{2}x$ was used for the 16 to 18 group. See the graph for the chest, Figure 9.2. The same procedure was employed for all projections.

Adjustment of the kilovoltage should always be made when a *new* projection is established. Just as soon as new conditions are introduced into a standard projection, then it should be considered a new one and factors should be laid down to satisfy the requirements of that projection.

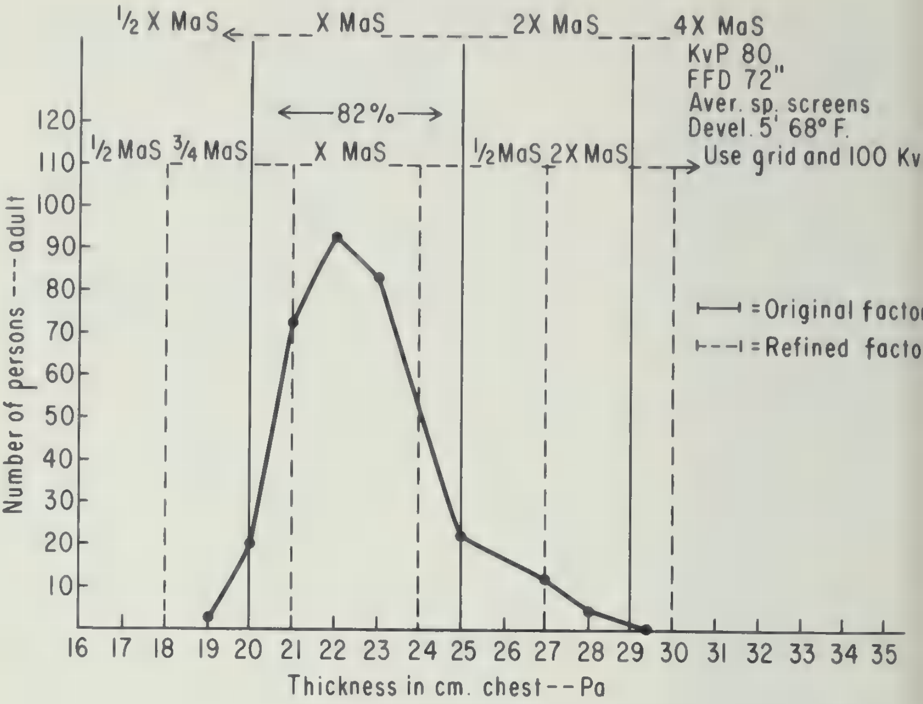


Figure 9.2. Graph for the chest.

It is not possible to construct a technique chart that is precisely workable on all types and makes of apparatus because of varying degrees of calibration efficiency. The best that can be accomplished is a compromise in which all factors but one are reduced to constants. The variable factor employed should have only one function—to influence the amount of silver deposited on the film (radiographic density).

No technique chart is a cure-all or an answer to good radiography. It is only an aid in that direction. Training in positioning, the application of suitable immobilization devices, and cones and grids (when employed), all contribute to the quality of the radiograph. Clinical experience in estimating the relative x-ray absorption characteristics of the patient as altered by disease, trauma, or age also has a decided bearing upon the results. Adjustments for relative absorption can be approximated by using Ma.S. values in the next lower or higher thickness category.

The exposure charts in this chapter, which are designed for use with full-wave rectified equipment, list suggested exposures for various routine projections. It may be found practical to adapt these factors to the routine radiographic work required by your department. It is most important that the appropriate Ma.S. and Kv.P. values, suffixed by the same symbol, be used together. Cones of the correct size must also be employed, as well as standardized processing.

THICKNESS RANGES

The thickness ranges of body parts in the adult patient are always measured along the course of the central ray. In most instances, three thickness ranges are specified. The first comprises a thickness range for *thin* parts; the second, the *average* thickness range which includes the majority of thicknesses for a given projection; and the third, the thickness range for the *heavy* parts.

Some projections, such as those for the chest, require a greater breakdown in thicknesses to attain the desired uniformity in radiographic quality.

FOCUS–FILM DISTANCE (FFD)

In the charts, the focus–film distances are standardized at 30–36 and 72 inches. If the FFD is to be changed at any time, the inverse square law should be used to effect the required change in Ma.S.

FILTRATION

The following techniques are based on the use of 2-mm. aluminum external filtration.

GUIDE Ma.S. VALUES

As a starting point in adapting the charts to your requirements, Guide Ma.S. values are listed for the various projections. These are trial values, but they are quite close to a corrected value that should be employed. Next is the column listing fixed kilovoltages. The kilovoltages listed have been attained by extensive experiment and are premised upon the following criteria:

1. That the wave length generated by the kilovoltage will provide radiation that will penetrate a given part when a practical Ma.S. value is used.
2. That the level of secondary radiation fog is such that it will not interfere with the diagnostic quality of the radiographic image.
3. That the image will exhibit a long scale of contrast to assure the rendition of maximum image detail.
4. That the final Ma.S. value selected for the average thickness will provide sufficient over-all image silver to reveal essential details. Since all factors but Ma.S. are constant, it can readily be seen that the level of radiographic density must be regulated by Ma.S. The kilovoltage should not be used for this purpose.
5. That the focus–film distances listed will assure satisfactory image sharpness.

The last column of the charts indicates the appropriate size of film required and the size of the cone needed to enclose the anatomic area specifically required.

USE OF CHARTS

Select the projection that is to be standardized. Choose a patient or phantom whose thickness is a median in the average thickness range. This thickness should be measured along the course of the central ray. Once the thickness category into which the part falls is determined, note the Guide Ma.S. listed for that particular thickness range. Make an exposure of the patient or phantom employing the indicated Ma.S., FFD, Kv.P., size of film, and cone. If the over-all density of the radiograph is greater than desired, repeat the exposure using the Guide Ma.S. value for the next lower thickness category. If the density is less than desired, use the Guide Ma.S. value listed for the next higher thickness. Further small adjustments in Ma.S. can be made to arrive at the exact density level desired. Once the density level for the average thickness is determined, the *percentage* increase or decrease in Ma.S. can be easily determined and the other Ma.S. values corrected accordingly. Simplification of this procedure can be effected by classifying radiography into these three types: (1) direct exposure, (2) screen exposure, and (3) screen-grid exposure. By this means, only three adjustments in the Guide Ma.S. values need be made for each class of radiography.

Fixed voltage technique is dependent upon a rigid application of the following factors:

1. Focus-film distance—
    - *a.* Influences the sharpness and magnification of the radiographic image.
    - *b.* Influences radiographic density.
2. Kilovoltage (Kv.P.)—
    - *a.* Regulates wave length of radiation.
    - *b.* Determines degree of penetration.
    - *c.* Influences production of secondary radiation fog.
    - *d.* Regulates scale of radiographic contrast.
    - *e.* Determines degree of exposure latitude.
    - *f.* Influences radiographic density.
3. Milliampere seconds (Ma.S.)—
    - *a.* Regulates the quantity of x-radiation emitted by the x-ray tube.
    - *b.* Regulates radiographic density.

The physiological or diseased state of the patient requires some adjustment of the Ma.S. values when an increase in tissue absorption occurs. A corresponding increase in over-all radiographic density is required. Doubling the Ma.S. is often sufficient compensation for

1. Sclerosis
2. Fluid or pus
3. Contrast media

Conditions which cause a decrease in tissue absorption require a corresponding decrease in radiographic density. Halving the Ma.S. often compensates for

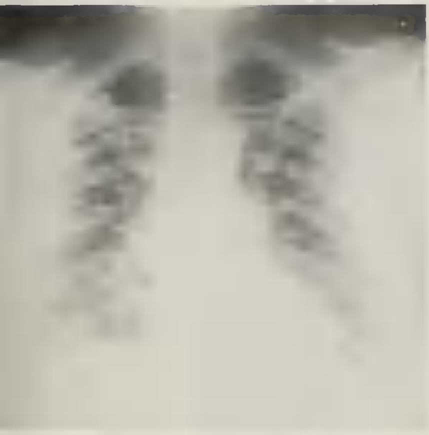
1. Destructive bone disease
2. Malignant metastases
3. Malnutrition
4. Atrophy
5. Emphysematous tissue

Example: In the postero-anterior adult chest to visualize the bronchi with opaque media, we find that the 17–20-cm. technique calls for 80 Kv.P. and 5 Ma.S. Since an opaque medium has been added, our initial procedure would be to double the Ma.S. (10 Ma.S.) and leave all other factors constant. If the new Ma.S. produces more density than desired, we go "in between" 5 and 10 Ma.S. and use 7.5 Ma.S. See Figure 9.10, oblique bronchogram exposure.

When a chest (or any other part) measures greater than average, the only change that need be made in the technical factors is in the Ma.S. The increased thickness requires more radiation. The Kv.P. is held constant since it has been established that 80 Kv.P. provides the necessary quality of radiation to penetrate any adult chest of normal size.

Figure 9.3 shows a 38-cm. chest exposed at 20 Ma.S. and 80 Kv.P. For best results, chests of thickness greater than 33 cm. require an increase not only in Ma.S. but also in kilovoltage. Therefore, the Kv.P. is raised to 100 in order to increase penetration. Secondary radiation fog should be eliminated by the use of a stationary parallel grid.

Figure 9.4 is the same chest but with the addition of a grid and 20 Kv.P. An increase of 5 to 10 Ma.S. is also indicated.



e 9.3. Chest, at 80 Kv.P. and 20 Ma.S.

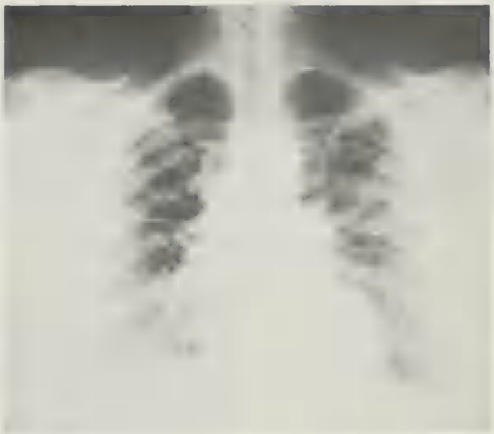


Figure 9.4. Chest, at 100 Kv.P. and 20 Ma.S. with grid.

If we were to use the basic Ma.S. (6.66) for a 15-cm. chest, the density would be excessive. A satisfactory result can be obtained, however, by using $^{1}/_{2}$ Ma.S. To balance the densities for the 17- and 20-cm. chest, $^{3}/_{4}$ x Ma.S. may be used. For chests that are 10–14 cm., $^{1}/_{4}$ Ma.S. may be used.

It is impossible to formulate a technique chart that will produce identical results in Durham, North Carolina, and Detroit, Michigan, and unless all machines in a particular department are calibrated the same and all cones and grids are identical, a separate chart must be worked out for each.

The following techniques are designed for use *only* with full-wave rectified equipment, a videx cone, 8-to-1 grid, and a rotating-anode tube. The exposure factors are the factors that produce excellent radiographs in one department. The factors, however, may be adapted to the equipment in your department by a simple adjustment in exposure.

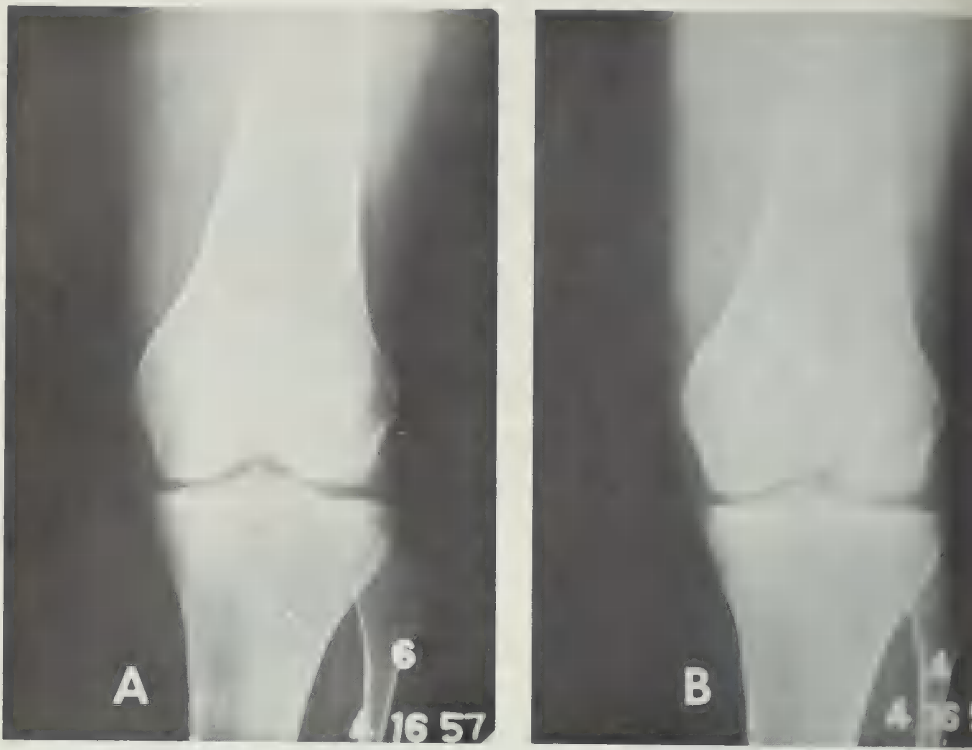
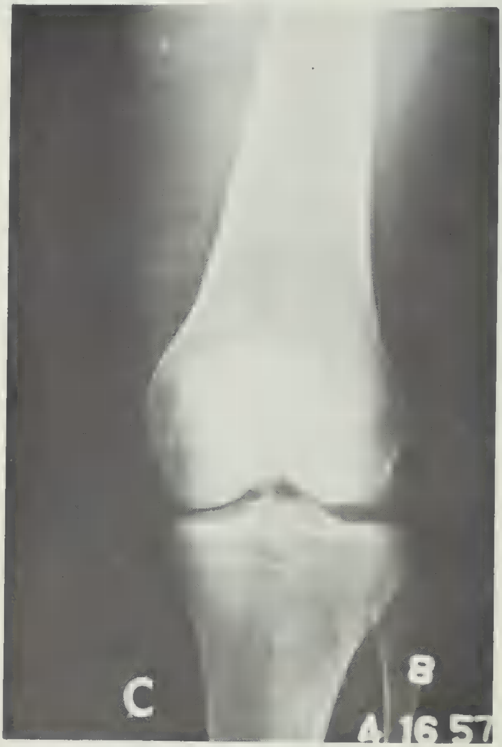


Figure 9.5. A.P. view of knee, with 8-to-1 grid: A – 6 Ma.S.; B – 4 Ma.S.; C – 8 Ma.S.



Adapting exposure charts to your equipment

Choose a patient of average build whose thickness falls into the average or middle class. Let us select the knee for a starting point. Measure the knee and use the *Guide Ma.S.* listed for the knee in the A.P. projection. Be sure to use the *Guide Ma.S., Focus–film distance, Kv.P., size of film,* and *cone* as listed. Repeat the exposure using the *Guide Ma.S.* value listed for the first class. Repeat the exposure using the *Guide Ma.S.* for the third or large class. Develop the three films at 68° for 5 minutes. Observe the three radiographs to find the desired density level for the average thickness. The percentage increase or decrease in Ma.S. can now be determined and the other Ma.S. values corrected accordingly. This correction factor will hold true for all radiography of parts with *similar density* (i.e., knee, leg). This procedure is followed for all groups; skull, sinuses, the lateral cervical spine, the lumbar spine, etc.

Example 1: For an A.P. radiograph of the knee employing an 8-to-1 grid, the Guide Ma.S. for the average thickness range (10–14 cm.) is 6. Make a second exposure employing the Guide Ma.S. for the first class (−9 cm.), 4 Ma.S., and a third exposure employing the Guide Ma.S. for the large class (14-cm.), 8 Ma.S. See Figure 7.1A, B, C. We find upon inspection of the three radiographs that 8 Ma.S. gives us the desired density. We now *divide the listed Guide Ma.S.* into the *corrected Ma.S.* to find the percentage or correction factor.

Thus

$$\begin{array}{r} 1.3 \\ 6\,\overline{)8.0} \\ \underline{6} \\ 20 \\ \underline{18} \\ 2 \end{array}$$

Therefore our correction factor is 1.3. We now multiply the Guide Ma.S. of *each class* by 1.3.

We now have 5 Ma.S. for the first class, 8 Ma.S. for the second class, and 10.4 or 10 Ma.S. for our large class. Make *no other changes.*

If by chance radiograph number 2, made with 4 Ma.S., is better, we would divide 6 into 4.

$$\begin{array}{r} .66 \\ 6\,\overline{)4.0} \\ \underline{3\,6} \\ 40 \\ \underline{36} \\ 4 \end{array}$$

We then would use .66 times the listed guide Ma.S. values. Or, we could say, $^{4}/_{6} = ^{2}/_{3}$; therefore $^{2}/_{3}$ times the guide Ma.S. values.

Example 2: In radiography of the skull in the A.P. projection (16-23 cm.), the guide Ma.S. will be found to be 30. If the resulting density is excessive, another exposure should be made employing 20 Ma.S., the value needed for a smaller skull. If the resulting density is satisfactory, the percentage reduction in Ma.S. needed is obtained in the following manner:

Guide Ma.S.	30
Corrected Trial Ma.S.	20

$^{20}/_{30} = ^{2}/_{3}$ or $66^{2}/_{3}$ per cent adjustment for the other Guide Ma.S. values listed for skull radiography. This procedure should be followed for other parts of similar density.

$$\begin{array}{r} .66^{2}/_{3} \\ 30\,\overline{)20.00} \\ \underline{180} \\ ^{20}/_{30} = ^{2}/_{3} \end{array}$$

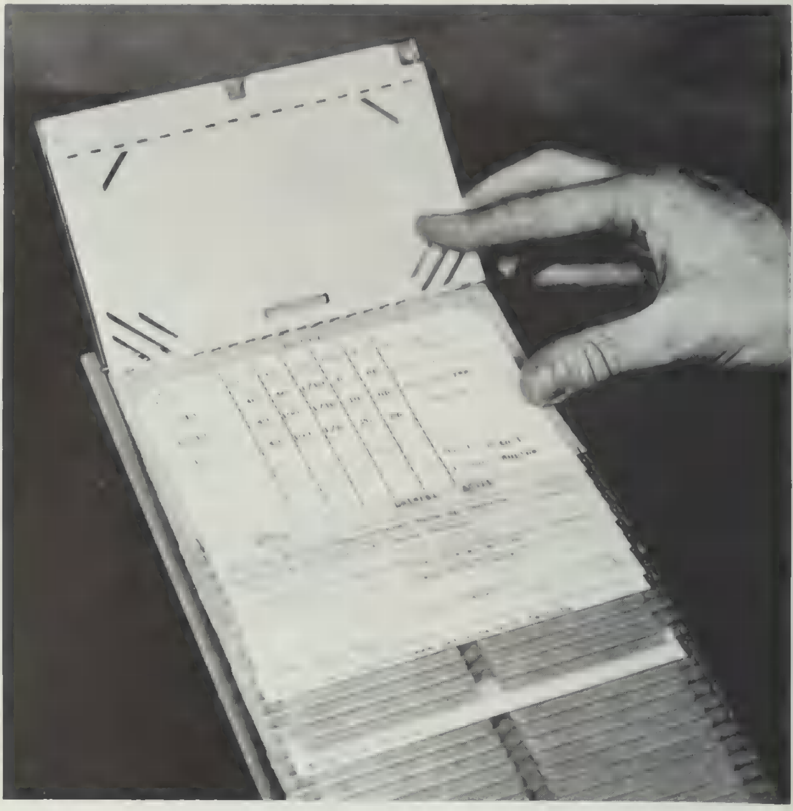


Figure 9.6. A Kardex technique file; below, a specimen card.

Thickness range: Cms.	*FFD*	*Guide Ma.S.*	*Ma.*	*Time*	*Ma.S.*	*Kv.P.*	*Legend*
Infant –							*F* – Cardboard
Child –							Ⓢ – *Screens, aver. speed*
8–12	36	10	100	$^1/_{10}$	10	85	Ⓖ – *Grid* *Cone no.* V-10 Development: 5 min. 68° *F.* *or automatic*
12–17	36	15	100	$^3/_{20}$	15	85	
17–21	36	20	100	$^1/_5$	20	85	
–							

SKULL	Lateral	*Film size* 10 x 12	*Projection no.* 15

A Kardex-type technique chart may be set up and each projection recorded; see Figure 9.6. The 4 x 6 cards in the Kardex technique file may be arranged as in the table below.

TABLE 9.2 ARRANGEMENT OF KARDEX FILE

Chest	P.A. Oblique Lateral Stretcher Table Bucky P.A.-Grid – Upright Oblique-Grid – Upright Lateral-Grid – Upright
Skull	Lateral A.P.-P.A. – Waters Brow Up Petrous Mentovertex Mastoid – Lateral Stenvers – P.A. Optic – P.A. Mandible – P.A. Mandible – Lateral
Sinuses	Lateral Frontal Sphenoid – Maxillary
Spine	Cervical – A.P. Cervical – Lateral Cervical – Oblique Neck – Soft Tissue Dorsal – A.P. Lumbar – A.P. Lumbar – Oblique Lumbar – Lateral Lumbar – Spot, L-5
Pelvis	A.P. Lateral
Hip	A.P. Lateral
Gallbladder	P.A. Upright Decubitus
Colon	Regular Air Contrast Chassard – Lapine
Pelvimetry	A.P. A.P. Inlet Lateral Placenta
Extremities	Hand Forearm Elbow Humerus Shoulder Foot Os Calcis Tibia – Fibula Knee
Extremities-screens	Adult Child Infant
G.I. Series	P.A. – Oblique

SPECIAL PROCEDURES

Contrary to some opinion, not all chest radiography with fixed kilovoltage is done at 80 Kv.P. Figure 9.7 is a radiograph of a chest of a premature infant at 60 Kv.P. The actual exposure factors were: 40-inch focus-film distance, medium screens, cylinder cone, 60 Kv.P., 3.33 Ma.S. (200 Ma for $^1/_{60}$ second).

Figure 9.10 illustrates an oblique bronchogram radiograph exposure at 100 Kv.P., 13.33 Ma.S., 72-inch FFD, 8-to-1 grid.

Figure 9.11 is an antero-posterior radiograph of the thoracic-lumbar spine. Since pathology was present, a spot-film for more detail and contrast was requested. By using the same exposure factors, reducing the distance from 36 to 30 inches and using a cylinder cone, we obtained the radiograph shown in Figure 9.12.

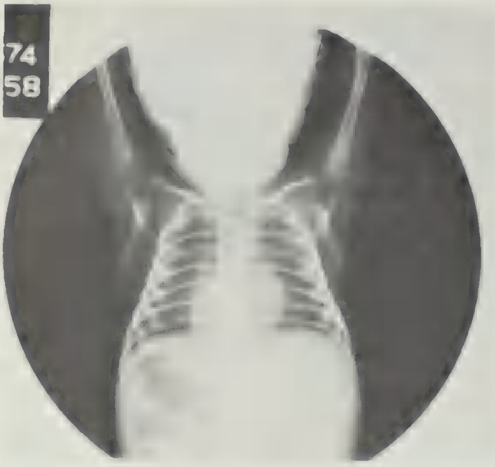


Figure 9.7. Chest of premature infant at 60 Kv.P.

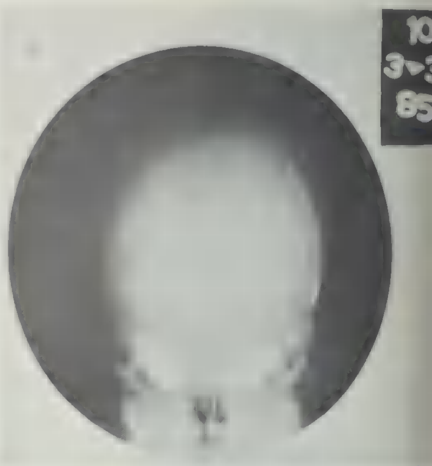


Figure 9.8. (above) A.P. view of skull of prema
infant at 85 Kv.P.

Figure 9.10. (right) Oblique bronchogram at 100 Kv.P.

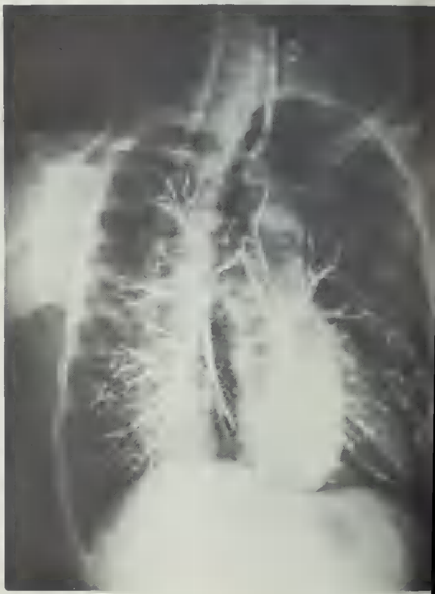


Figure 9.9. A.P. view of pelvis of 8-year-old child at 70 Kv.P.

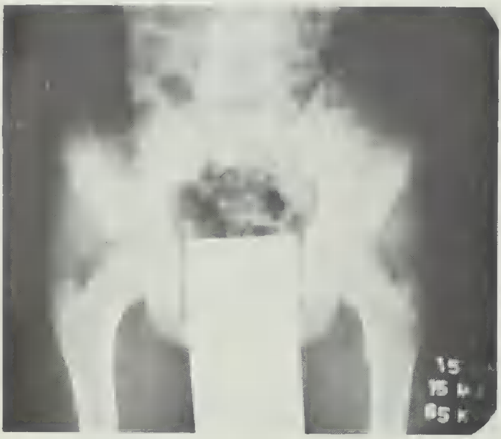
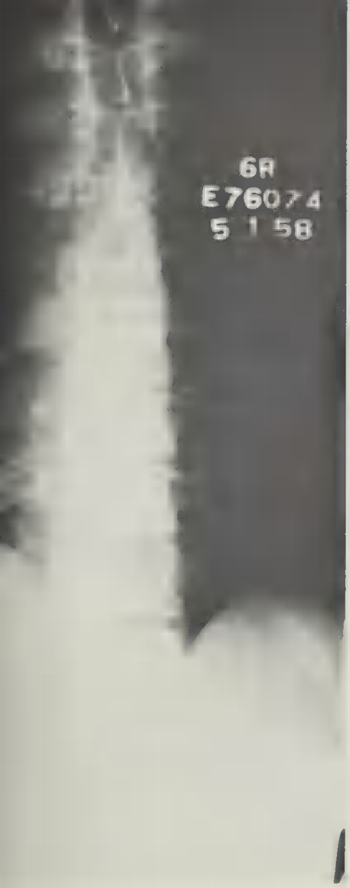


Figure 9.13 is a radiograph of an air-contrast colon employing 100 Kv.P., 15 Ma.S., 36-inch FFD, 8-1 grid.

Figure 9.14 shows pathology at the level of the first lumbar vertebra. Note the detail and contrast shown at the level of L-1 and 2 and L-4 and 5. The exposure factors were 85 Kv.P. and 150 Ma.S.

Other examples of fixed voltage are shown in Figure 9.15.



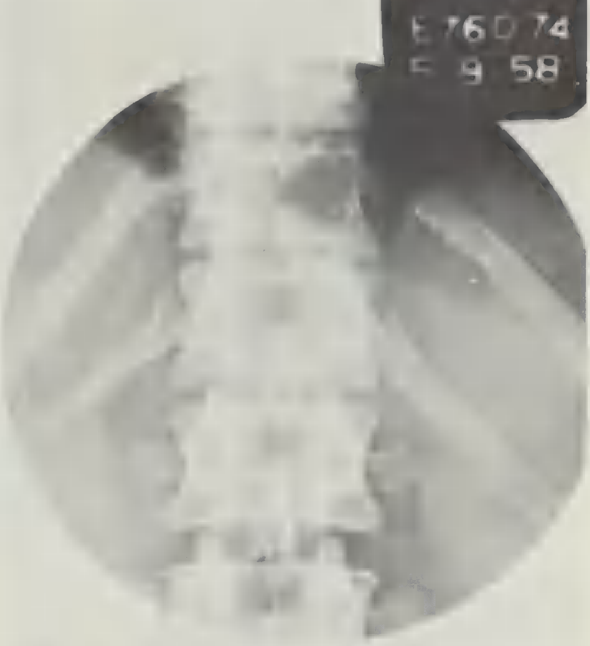
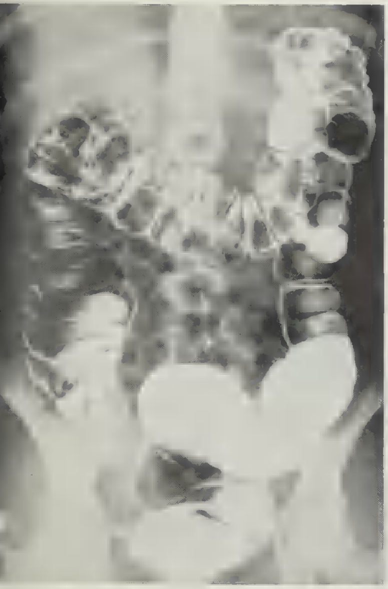


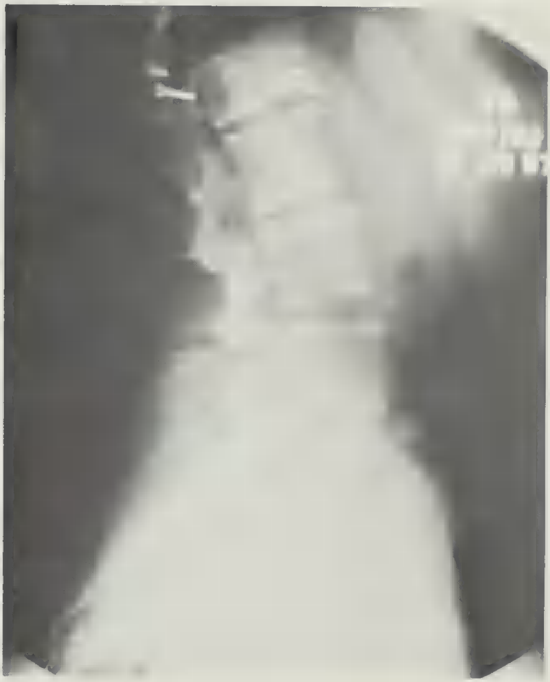
Figure 9.11. (left, above) A.P. view of dorsal and lumbar spine.

Figure 9.12. (right, above) Spot film showing pathology, in spine of Figure 9.11.

Figure 9.13. (left, below) Air-contrast colon.

Figure 9.14. (right, below) Note the pathology at the level of the first lumbar vertebra.





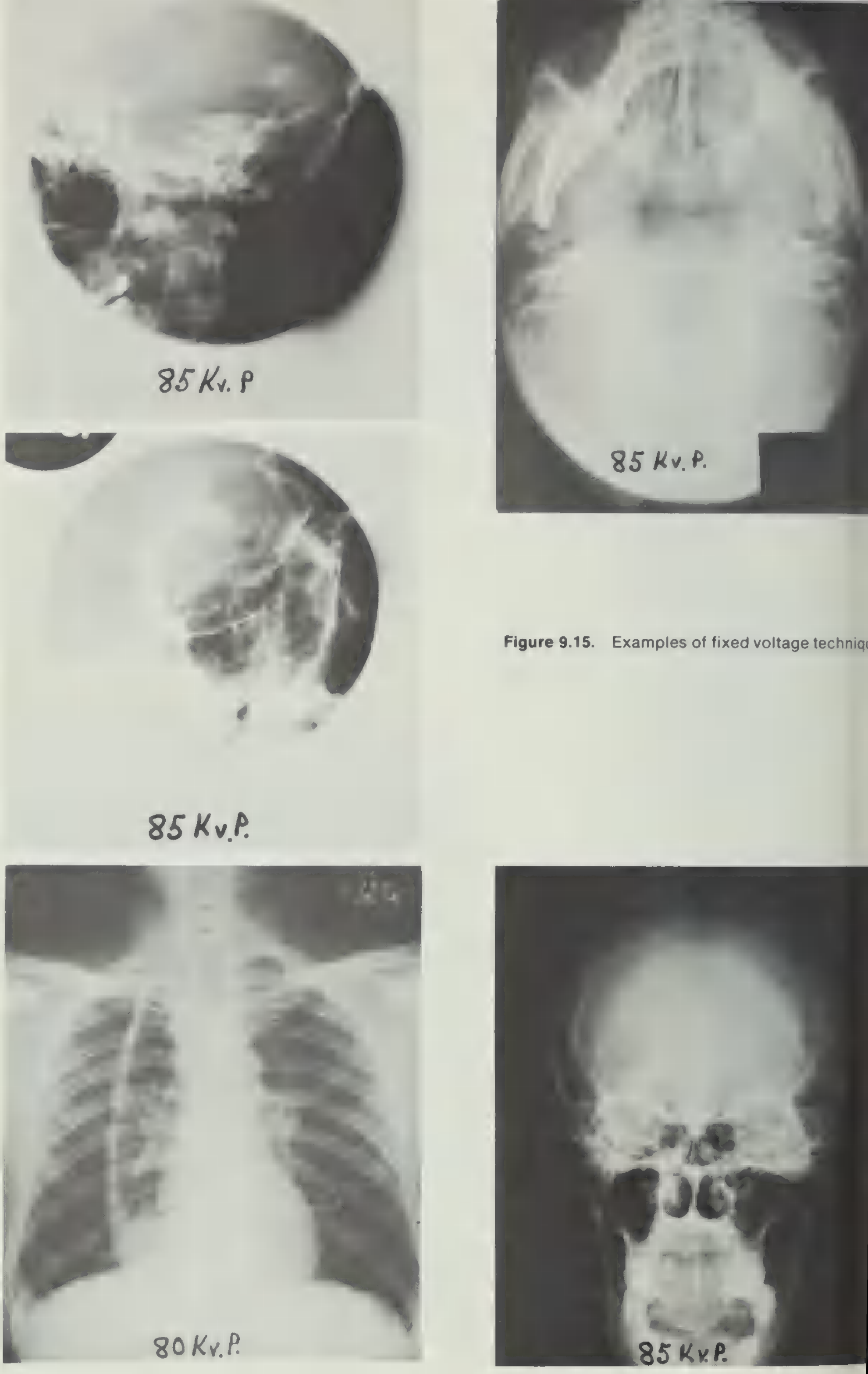


Figure 9.15. Examples of fixed voltage techniq

EXPOSURE CHARTS: FIXED KILOVOLTAGE TECHNIQUES (adult)

Projection: Proj.
Centimeters: Cm.
Distance: FFD (Focus–film)
Videx Cone: V
Cylinder Cone: C
Tube: Rotating Anode

Cardboard and Regular Film: F
Screens, Medium: S
Screens and 8-to-1 Grid: SG
Filter: 2 mm. al.
Development: 5 minutes at 68°
Film: Regular

THE SKULL

Region	*Proj.*	*Cm. Range*	*FFD*	*Guide Ma.S.*	*Ma.*	*Time*	*Ma.S.*	*Kv.P.*	*Cone and Film*
Skull	*Lat.*	8–12	36″	10 SG				85 SG	V-12 10 x 12
		12–17		15 SG					
		17–22		20 SG					
	P.A.	13–17		15 SG					V-8 8 x 10
		17–21		25 SG					
		21–26		35 SG					
	A.P. 20°	13–17		20 SG					
		17–23		30 SG					
		23–27		40 SG					
	Axial	15–19		40 SG					
		19–25		50 SG					
		25–29		70 SG					
	Towne 35°	13–17	30″	40 SG					C 8 x 10
		17–24		60 SG					
		24–29		75 SG					
	Mastoid Law	9–12		10 SG					
		12–17		15 SG					
		17–20		20 SG					
	Stenvers	14–17		15 SG					
		17–21		25 SG					
		21–25		35 SG					
	Optic P.A.	13–17		15 SG					
		17–21		25 SG					
		21–26		35 SG					

Note: Automatic processing will require some adjustment in exposure factors.

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
	Facial Bones P.A.	13–17	36″	15 SG				85 SG	V-8 8 x 10
		17–21		25 SG					
		21–26		35 SG					
Nose	Lat.	1.5–4	30″	70 F 2.5 S				50 F 70 S	C 8 x 10
Mandible	Lat.	6–10		2.5 S				70 S	
		10–14		5 S					
	P.A.	10–14		5 SG				85 SG	
		14–17		10 SG					
Sinuses	Lat.	9–12		2.5 S 2.5 SG				70 S 85 SG	
		12–17		7.5 S 10 SG				70 S 85 SG	
		17–21		10 S 15 SG				70 S 85 SG	
	P.A. Front P.A. Max.	14–17		20 S 15 SG				70 S 85 SG	
		17–21		25 S 25 SG				70 S 85 SG	
		21–25		30 S 30 SG				70 S 85 SG	
	Open Mouth Sphenoid	14–17		20 S 20 SG				70 S 85 SG	
		17–22		30 S 30 SG				70 S 85 SG	
		22–26		40 S 40 SG				70 S 85 SG	

THE CHEST

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Chest	P.A.	14–17	72″	3.33 S				80 S	V-14 14 x 17
		17–20		5 S					
		20–24		6.66 S					
		24–28		10 S					

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Chest	P.A.	28–31	72"	15 S				80 S	V-14 14 x 17
		31–35		20 S					
	Obl.	15–19		3.33 S				85 S	
		19–23		6.66 S					
		23–29		13.33 S					
		29–34		20 S					
	Lat.	22–26		13.33 S				90 S	
		26–31		15 S					
		31–35		20 S					
	P.A.	19–24		10 SG				100 SG	
		24–28		15 SG					
		28–31		25 SG					
		31–36		40 SG					
	Obl.	19–24		10 SG				100 SG	
		24–29		20 SG					
		29–35		40 SG					
	Lat.	24–27		15 SG				110 SG	
		27–30		20 SG					
		30–35		30 SG					
		35–40		50 SG					

THE SPINE AND PELVIS

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Cervical	Lat. and obl.	6–9	72"	6.5 S				85 S	V-8 8 x 10
		9–13		15 S					
		13–18		20 S					
	Lat. Soft tissue	6–9		3.2 S					
		9–13		5 S					
		13–18		10 S					

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Cervical	A.P.	8–11	36"	10 SG				80 SG	V-8 8 x 10
		11–15		15 SG					
		15–20		20 SG					
Thoracic	A.P.	16–19		40 SG				75 SG	V-7 7 x 17 or 11 x 14
		19–24		60 SG					
		24–29		80 SG					
	Lat.**	26–30		50 SG				80 SG	
		30–34		100 SG					
		34–39		150 SG					
Lumbar	A.P.	13–17		60 SG				70 SG	V-11 11 x 14
		17–22		80 SG					
		22–27		100 SG					
	Obl.	15–18		60 SG				75 SG	V-8 8 x 10
		18–22		80 SG					
		22–27		100 SG					
	Lat.	23–26		100 SG				85 SG	V-11 11 x 14
		26–32		200 SG					
		32–37		275 SG					
Pelvis	A.P.	12–15		50 SG				65 SG	V-14 14 x 17
		15–20		80 SG				70 SG	
		20–25		100 SG					
		25–29		125 SG					
Hip	A.P.	14–17	36"	40 SG				80 SG	V-10 8 x 10
		17–21		60 SG					
		21–25		80 SG					
	Lat. (Rotation)	15–19		50 SG					
		19–23		60 SG					
		23–26		80 SG					

**LAT. THORACIC: Patient breathing. Use a low Ma. station and long exposure time. Example: Technique calls for 100 Ma.S. Use 25 Ma. and 4 seconds exposure.

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Hip	Lat. (True)	17–20	36″	125 SG				80 SG	C 8 x 10
		20–25		150 SG					
		25–30		175 SG					
Abdomen	A.P.	14–19		75 SG				70 SG	V-14 14 x 17
		19–23		100 SG					
		23–26		125 SG					
		26–31		150 SG					
Gallbladder	P.A.	14–17		20 SG				75 SG	V-10 10 x 12
		17–22		30 SG					
		22–25		60 SG					
		25–30		100 SG					

GASTRO-INTESTINAL: COLON AND PELVIMETRY

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Colon	A.P. P.A.	15–18	36″	5 SG				100 SG	V-14 14 x 17
		18–21		10 SG					
		21–25		20 SG					
		25–29		40 SG					
		29–33		80 SG					
	Chassard Lapine	19–22		50 SG					
		22–26		75 SG					
		26–30		100 SG					
G.I.	A.P. P.A. Oblique	15–20		20 SG				90 SG	V-10 10 x 12
		20–23		40 SG					
		23–26		75 SG					
		26–30		90 SG					
		30–34		100 SG					

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Esophagus	P.A. Oblique	15–20	36″	10 SG				90 SG	V-11 or V-7 11 x 14 7 x 17
		20–23		20 SG					
		23–26		30 SG					
		26–30		40 SG					
		30–34		50 SG					
Pelvimetry	A.P. Supine	20–23		100 SG				75 SG	V-14 14 x 17
		23–28		150 SG					
		28–33		200 SG					
	Thoms A.P.	24–27		100 SG				100 SG	V-10 10 x 12
		27–32		150 SG					
		32–36		200 SG					
	Lat.	23–26		80 SG					V-14 14 x 17
		26–32		100 SG					
		32–25		150 SG					

THE EXTREMITIES

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Hand Wrist	P.A.	–2	36″	50 F				50 F 60 S	V-8 8 x 10
		3–5		70 F 1.66 S					
		5–8		90 F 2.5 S					
	Lat.	7–10		120 F 5 S					
		10–14		150 F 7.5 S					
Forearm	A.P. P.A. Lat.	3–6		60 F 2.5 S				60 F 60 S	V-11 11 x 14
		6–10		70 F 2.5 S					
		11–14		80 F 4.16 S					

The Fixed Kilovoltage System

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Elbow	*A.P.* *Lat.*	3–6	36″	60 F 1.66 S				60 F 60 S	V-8 8 x 10
		6–10		100 F 2.5 S					
		10–14		120 F .5 S					
Shoulder Upper 1/3 Humerus	*A.P.* *Lat.*	8–12		7.5 SG				80 SG	V-8 8 x 10
		12–16		12.5 SG					
		16–20		15 SG					
		20–24		20 SG					
Foot	*A.P. and Obl.*	3–6		60 F 1.66 S				60 F 60 S	V-10 10 x 12
		6–10		70 F 2.5 S					
		10–14		80 F 3.5 S					
	Lat.	3–6		80 F 3.33 S					
		6–10		100 F 5 S					
		10–14		120 F 7.5 S					
Os calcis	*Axial*	5–8		75 F				80 F	C 8 x 10
		8–13		100 F					
		13–17		125 F					
Tibia Fibula	*A.P.*	6–8		5 SG				80 SG	V-7 7 x 17
		8–12		10 SG					
		12–15		15 SG					
	Lat.	5–7		2.5 SG					
		7–11		3.2 SG					
		11–15		5 SG					
Knee	*A.P.*	7–9		5 SG					V-8 8 x 10
		9–14		6.5 SG					
		14–17		10 SG					

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Knee	Lat.	6–8	36″	5 SG				80 SG	V-8 8 x 10
		8–13		6.5 SG					
		13–15		7.5 SG					

THE EXTREMITIES

Screen exposure only

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone and Film
Hand	P.A. or Obl.	2–5	36″	1.66 S				60 S	To part
		5–8		2.5 S					
Wrist	P.A. Lat. Obl.	2–5		1.66 S					
		5–10		2.5 S					
Forearm	A.P. Lat.	3–6		1.66 S					
		6–10		2.5					
		10–15		4.16					
Elbow	A.P. Lat. Obl.	3–5		1.66 S					
		5–10		2.5 S					
		10–15		5 S					
Ankle	A.P. Lat. Obl.	4–8		3.33 S					
		8–12		6.6 S					
		12–15		10 S					
Leg	A.P. Lat.	4–8		3.33 S					
		8–13		6.66 S					
		13–17		10 S					
Knee	A.P. Lat.	4–8		3.33 S					
		8–13		6.66 S					
		13–17		10 S					

Note: Cast, add 10 Kv.P.

EXPOSURE CHARTS: FIXED Kv.P. TECHNIQUE (Infants and Children)

S – Screens, Average speed	C – Cylinder Cone
SG – Screens and Grid (8-1)	V – Videx
F – Regular film and Cardboard holder	Dev. 5 min. at 68 degrees
Filter – 2.5-mm Al.	

Region	*Proj.*	*Cm. Range*	*FFD*	*Guide Ma.S.*	*Ma.*	*Time*	*Kv.P.*	*Cone*
Chest (premature)	*A.P.*	5–9	40″	3.3 S	200	1/60	60	C
Chest (table top)	*A.P.*	10–14	60″	2.5 S	50	1/20	75	*To part*
		15–18		4 S	125	1/30	70	
		19–21		6 S	125	1/20	70	
	Obl.	12–15		4 S	125	1/30	75	
		16–18		6 S	125	1/20		
		19–21		8 S	125	1/15		
	Lat.	12–15		4 S	125	1/30	80	
		16–19		6 S	125	1/20		
		20–22		8 S	125	1/15		
Chest (upright)	*P.A.*	14–17		3.33 S	100	1/30	80	*To part*
		18–20		5 S	100	1/20		
	Obl.	12–15	72″	6 S	125	1/20	75	
		16–18		8 S	125	1/15		
		19–21		6.7 S	200	1/30	85	
		22–25		8.5 S	125	1/15		
	Lat.	12–15		3.3 S	100	1/30	90	
		16–19		5 S	100	1/20		
		20–23		6.7 S	200	1/30		
		24–26		8.5 S	125	1/15		

Note: For automatic processing reduce Kv.P. by 10 Kv. and adjust the Ma.S.

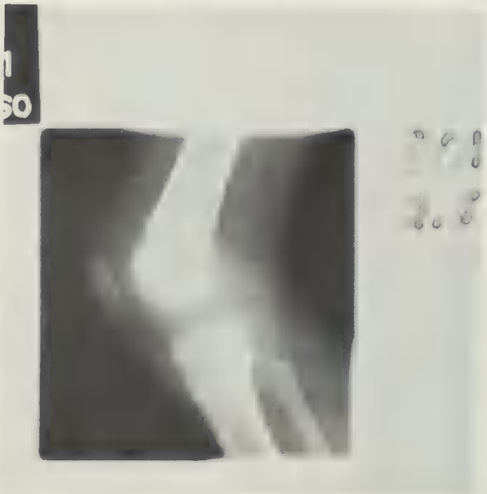
Region	Proj.	Cm. Range	FFD	Guide Ma. S.	Ma.	Time	Kv.P.	Cone
Skull	A.P.	9–12	36″	3.3 SG	50	1/15	85	V-8
		12–15		6.6 SG	100	1/15		
		16–20		13.3 SG	200	1/15		
		21–22		20 SG	200	1/10		
	Lat.	9–12		2.5 SG	25	1/10		
		13–17		7.5 SG	50	3/20		
		18–21		10 SG	100	1/10		
	Mento-vertex	12–16		15 SG	100	3/20		
		17–21		25 SG	100	1/4		
		22–25		40 SG	200	1/5		
		26–29		60 SG	200	3/20		
	Petrous A.P.	9–12		10 SG	100	1/10		C
		12–15		20 SG	200	1/10		
		16–20		30 SG	200	3/20		
		21–25		50 SG	200	1/4		
	Stenvers	12–16	30″	15 SG	100	3/20		
		17–23		20 SG	200	1/10		
	Optic	10–14		5 SG	50	1/10		
		15–18		10 SG	100	1/10		
		19–22		20 SG	200	1/10		
	Mastoid Lat.	6–9		2.5 SG	25	1/10	75	
		10–13		5 SG	50	1/10		
		14–17		7.5 SG	50	3/20		
	Sinuses P.A.	11–16		10 SG	100	1/10	85	
		17–23		20 SG	200	1/10		
	Sinuses Lat.	4–8		2.5 S	25	1/10	80	
		9–12		5 S	50	1/10		
		13–16		7.5 S	50	3/20		

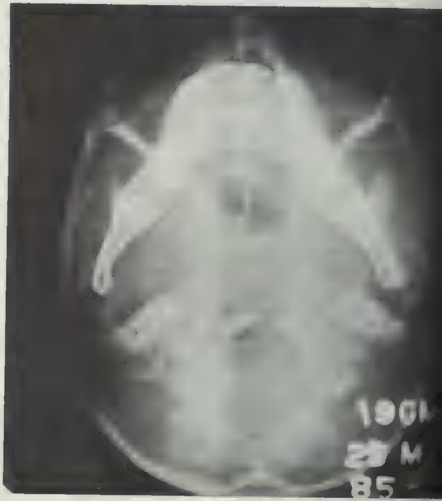
The Fixed Kilovoltage System

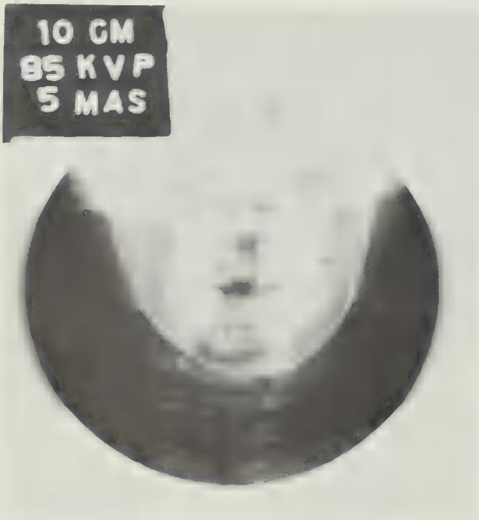
Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Kv.P.	Cone
Skull	Mandible P.A.	4–8	30"	2.5 SG	50	1/20	85	C
		9–13		5 SG	100	1/20		
		14–18		10 SG	200	1/20		
	Mandible Lat.	4–8		1.2 S	25	1/20	70	
		9–11		2.5 S	50	1/20		
		12–15		5 S	100	1/20		
Cervical Spine	Lat. & Obl.	3–6	72"	5 S	100	1/20	85	
		7–11		10 S	200	1/20		
		12–15		15 S	300	1/20		
	A.P.	3–6	36"	5 SG	50	1/10	80	
		7–11		10 SG	100	1/10		
		12–15		20 SG	200	1/10		
Thoracic	A.P.	10–15		10 SG	100	1/10	75	
		16–19		20 SG	200	1/10		
		20–23		40 SG	200	1/5		
	Lat.	14–19		7.5 SG	50	3/20	80	
		20–24		10 SG	25	4/10		
		25–28		20 SG	50	4/10		
Lumbar & Pelvis, & Abdomen	A.P. & Obl.	7–11		10 SG	100	1/10	65	
		12–15		25 SG	100	1/4		
		16–19		40 SG	200	1/5		
		20–24		60 SG	200	3/10		
Extremities (Premature)	All			3.33 S	100	1/30	45	To part
Extremities	Wrist, Elbow, Forearm A.P. & Lat.	3–5		1.66 S	50	1/30	55	
		6–10		2.5 S	50	1/20		
		11–15		3.33 S	100	1/30		
	Ankle, Leg, Knee A.P. & Lat.	4–8		3.33 S	100	1/30		
		9–13		6.6 S	200	1/30		
		14–17		10 S	200	1/20		

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Kv.P.	Cone
Knee	A.P. Lat. Obl.	4–9	36"	2.5 SG	25	1/10	80	To part
		10–15		5 SG	50	1/10		
		16–18		10 SG	100	1/10		
Shoulder	A.P. Lat.	4–9		2.5 SG	25	1/10		
		10–14		5 SG	50	1/10		
		15–17		10 SG	100	1/10		

Figure 9.16. Examples of fixed voltage technique used for children.







HIGH KILOVOLTAGE TECHNIQUE

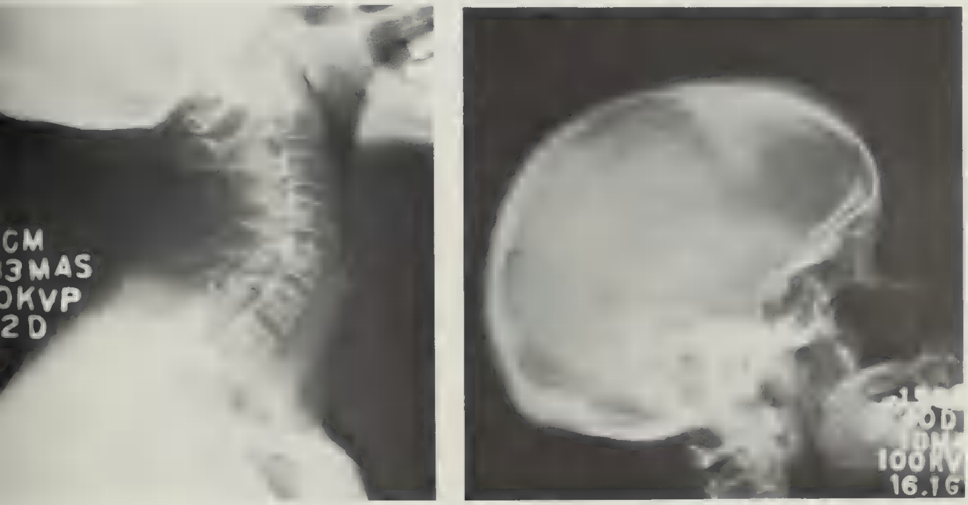
It is possible to produce films of as good quality with high kilovoltage as with low or medium kilovoltage. It is not necessarily a *fact* that radiographs produced by high kilovoltage are gray and flat. Inappropriate selection and control of milliampere seconds have been the most common errors when employing higher kilovoltages. The use of a 12-to-1 or a 16-to-1 grid and limiting the area of exposure are of primary importance.

Actually the only limit imposed on the amount of kilovoltage that might be employed in medical radiography is the limitation of contrast (long scale). The limit of course is the point at which the contrast scale becomes so long that diagnosis becomes doubtful. To maintain contrast at the higher kilovoltages the use of a 12-to-1 or a 16-to-1 grid is essential; however, chest radiography may be done up to 150 Kv.P. with a 7-to-1 or 8-to-1 grid.

In this country many departments use up to 130 Kv.P. There has been a general acceptance of an increase in the average voltage used in routine radiography. Voltage above 100 Kv.P. is being used for various radiographic examinations; notably, radiographic examinations of the gastro-intestinal tract, colon, air-contrast colon, pelvimetry, and lateral lumbar-sacral spine, and also non-screen grid exposures.

Supervoltage technique in chest radiography to visualize lesions overshadowed by bone have been done by Pendergrass, Tuddenham, and others.

Figure 9.17. Examples of high kilovoltage technique.



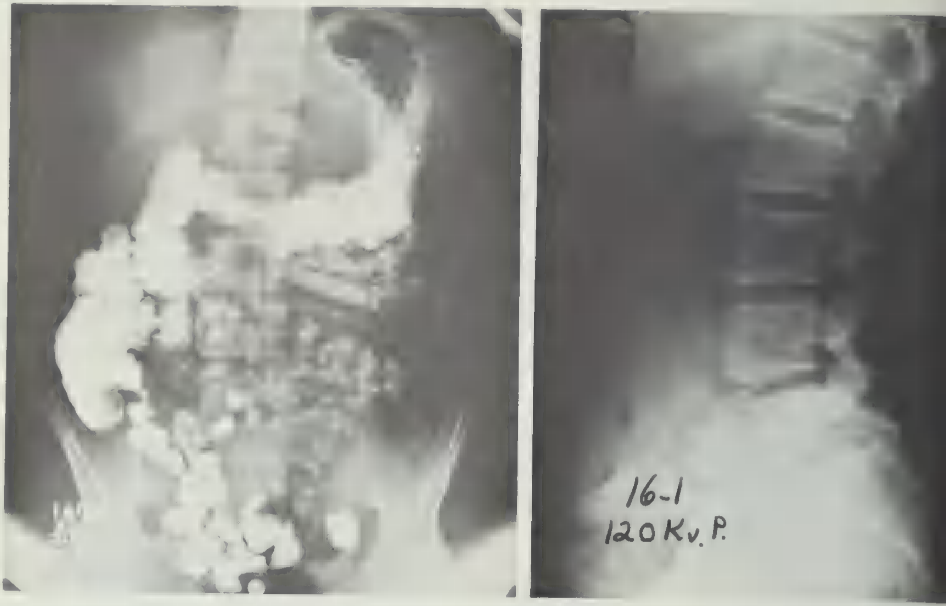
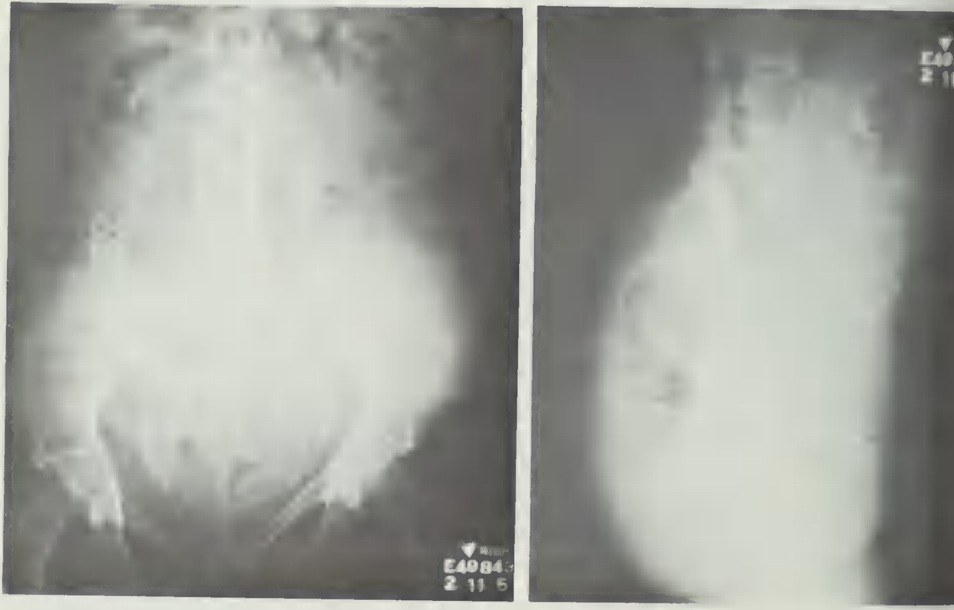


Figure 9.18. Examples of high kilovoltage technique.



FIXED HIGH-KILOVOLTAGE TECHNIQUE

Tube:	Super Dynamax Rotating-Anode
Grid:	16-to-1 Ratio
Cone:	Double Diaphragm Videx (V) Cylinder Cone (C)
Filter:	3 mm. external, ½ mm. internal
Projection:	Proj.
Thickness:	Cm.
Distance:	FFD
Regular film with cardboard holder:	F
No-screen film:	NS
Screens, medium:	S
Screens and grid:	SG (16-1)
Development:	5 minutes at 68°

Region	*Proj.*	*Cm. Range*	*FFD*	*Guide Ma.S.*	*Ma.*	*Time*	*Ma.S.*	*Kv.P.*	*Cone*
Skull	*Lat.*	12–17	40″	10 SG				100 SG	V-10
		17–20		12.5 SG					
	P.A. *A.P.*	17–21		17.5 SG					V-8
		21–25		25 SG					
	Towne	17–24		30 SG					C
		24–28		40 SG					
	Vertex	19–25		30 SG					V-8
		25–29		40 SG					
Cervical	*A.P.*	11–15	72″	10 SG					V-8
		15–18		15 SG					
	Lat.	9–13		8.33 S					
		13–15		12.5 S					
	Lat. Soft tissue	10–15		3.3 S					
		15–18		5 S					
Thoracic	*A.P.*	19–24	40″	25 SG					V-7
		24–29		30 SG					
	Lat.	30–34		40 SG					7 x 17
		34–38		50 SG					
Lumbar	*A.P.*	17–22		20 SG					V-11
		22–25		25 SG					11 x 14
	Obl.	17–22		25 SG					V-10
		22–25		30 SG					8 x 10

Note: Automatic processing will require some adjustment in exposure factors.

Region	Proj.	Cm Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone
Lumbar, cont.	*Lat.*	26–32	40″	50 SG				120 SG	V-11 11 x 14
		32–38		60 SG					
Pelvis	*A.P.*	19–23		25 SG				100 SG	V-14 14 x 17
		23–27		30 SG					
Abdomen	*A.P.*	23–26		25 SG					
		26–32		50 SG					
Gallbladder	*P.A.*	22–25		25 SG					V-10 10 x 12
		25–31		30 SG					
		31–33		40 SG					
Pregnancy	*A.P.*	23–28		30 SG				120 SG	V-14 14 x 17
		28–34		50 SG					
Pelvimetry	*A.P. Thoms*	24–27		50 SG					V-10 10 x 12
		27–32		75 SG					
		32–36		100 SG					
	Lat.	23–26		40 SG					V-14 14 x 17
		26–32		50 SG					
		32–37		75 SG					
Placenta	*Lat.*	Small		15 SG					
		Medium		20 SG					
		Large		30 SG					

G.I. series and colon

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone
G.I. and colon	*P.A. Obl. Lat.*	13–17	40″	6.66 SG				120	To Film
		17–22		10 SG					
		22–27		20 SG					
		27–32		33.3 SG					

The Fixed Kilovoltage System

Bronchogram—with grid cassette

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone
Lungs	P.A.	20–24	72″	10 SG				100	V-14 14 x 17
		24–27		15 SG					
		27–30		20 SG					
		30–34		30 SG					
	Obl.	19–23		10 SG					
		23–30		20 SG					
		30–35		40 SG					
	Lat.	24–27		15 SG					
		27–29		25 SG					
		29–33		30 SG					
		33–40		60 SG					

P.A. chest six-inch air-gap technique (see p. 229)

Region	Proj.	Cm. Range	FFD	Guide Ma.S.	Ma.	Time	Ma.S.	Kv.P.	Cone
Chest	P.A.	26–30	120″	5 S				125	To part 14 x 17
		30–35		8.3 S					
		35–40		15 S					

Extremities

Part	Position	Avg. Cm. Thickness	Kv.P.	Suggested Ma.S.		Selected Ma.S.		Dist.	Grid
				Cb. H.*	Screen	Cb. H.	Screen		
Hand	P.A.-Obl.	3–5	76	20	.83			40	No
Wrist	P.A.	4–6	76	25	1			40	No
Wrist	Lateral	5–8	76	50	2.08			40	No
Forearm	All	6–9	76	50	2.08			40	No
Elbow	A.P.	6–9	76	50	2.5			40	No
Elbow	Lateral	7–10	76	50	2.5			40	No
Humerus	All	7–10	100		7.5			40	16:1
Shoulder	A.P.	13–16	100		7.5			40	16:1

Part	Position	Avg. Cm. Thickness	Kv.P.	Suggested Ma.S.		Selected Ma.S.		Dist.	Grid
				Cb. H.*	Screen	Cb. H.	Screen		
Clavicle	A.P.	13–16	100		7.5			40	16:1
Foot	A.P.-Obl	7–9	76	25	2.08			40	No
Foot	Lateral	7–9	76	50	2.5			40	No
Os calcis	Axial	8–13	76	40	2.08			40	No
Ankle	A.P.	7–10	76	75	3.33			40	No
Ankle	Lateral	6–9	76	50	2.5			40	No
Leg	A.P.	9–12	76		3.33			40	No
Leg	Lateral	8–11	76		2.5			40	No
Knee	A.P.	11–14	100		7.5			40	16:1
Knee	Lateral	10–13	100		6.67			40	16:1
Patella	Axial		100		.83			40	No
Femur	A.P.	14–17	100		7.5			40	16:1
Femur	Lateral	13–16	100		6.67			40	16:1

**Cb. H.: Cardboard holder and regular filter.*

FIXED KILOVOLTAGE TECHNIQUE CHART–150 Kv.P.

Part	Position	Avg. Cm. Thickness	Kv.P.	Suggested Ma.S.	Selected Ma.S.	Dist.	Screen	Grid
Pelvis	A.P.	17–20	150	5		40	Yes	16:1
Lumbar spine	A.P.	17–21	150	7.5		40	Yes	16:1
Lumbar spine	Oblique	18–22	150	10		40	Yes	16:1
Lumbar spine	Lateral	24–26	150	15		40	Yes	16:1
Lumbar spine	Lateral	27–30	150	20		40	Yes	16:1
Lumbar spine	Lateral	31–34	150	30		40	Yes	16:1
Lumbar spine	Lateral	35–38	150	40		40	Yes	16:1
Dorsal spine	A.P.	21–24	150	4		40	Yes	16:1
Dorsal spine*	Lateral	30–34	150	2		40	Yes	16:1
Cervical spine	A.P.	11–14	150	2.5		40	Yes	16:1
Cervical spine	Oblique	10–13	150	1		72	Yes	No
Cervical spine	Lateral	11–14	150	1		72	Yes	No
Atlas & axis	A.P.	12–16	150	3.33		40	Yes	16:1

The Fixed Kilovoltage System

Part	*Position*	*Avg. Cm. Thickness*	*Kv.P.*	*Suggested Ma.S.*	*Selected Ma.S.*	*Dist.*	*Screen*	*Grid*
Lumbo-sacral jt.	Lateral	30–34	150	40		40	Yes	16:1
Lumbo-sacral jt.	Lateral	35–38	150	50		40	Yes	16:1
Lumbo-sacral jt.	Lateral	39–42	150	60		40	Yes	16:1
Hip	A.P.	17–21	150	5		40	Yes	16:1
Hip	Lateral	20–24	150	7.5		40	Yes	16:1

*Slow breathing.

Skull	Lateral	16–18	150	1.5		40	Yes	16:1
Skull	P.A.	18–21	150	3		40	Yes	16:1
Skull	Occiput	18–21	150	3.75		40	Yes	16:1
Skull	Sub-mentovert.	23–26	150	6.25		40	Yes	16:1
Sinuses	Maxillary	18–22	150	5		30	Yes	16:1
Sinuses	Frontal	18–22	150	5		30	Yes	16:1
Sinuses	Open-mouth	21–24	150	5		30	Yes	16:1
Sinuses	Lateral	11–14	150	1		30	Yes	16:1
Mastoid	Lateral	14–17	150	1.5		30	Yes	16:1
Mandible	P.A.	12–15	150	.83		40	Yes	16:1
Mandible	Lateral	10–13	76	2.5		30	Yes	No
Nose	Lateral		76	20		40	No	No

Part	*Position*	*Avg. Cm. Thickness*	*Kv.P.*	*Suggested Ma.S.*	*Selected Ma.S.*	*Dist.*	*Screen*	*Grid*
Esophagus	P.A.	20–25	150	2.08		40	Yes	16:1
Esophagus	Lateral	28–32	150	5		40	Yes	16:1
Stomach	P.A.	18–22	150	7.5		40	Yes	16:1
Colon	P.A.	18–22	150	7.5		40	Yes	16:1
Colon post evac.	P.A.	18–22	150	5		40	Yes	16:1
Gallbladder	P.A.	18–22	150	7.5		40	Yes	16:1
Abdomen	A.P.	17–21	150	6.67		40	Yes	16:1

Chest	P.A.	–14	150	.83		72	Yes	10:1
Chest	P.A.	15–17	150	1.67		72	Yes	10:1
Chest	P.A.	18–22	150	2		72	Yes	10:1
Chest	P.A.	23–25	150	3		72	Yes	10:1
Chest	P.A.	26–29	150	6		72	Yes	10:1
Chest	P.A.	30	150	8.33		72	Yes	10:1
Chest	Lateral	–26	150	4		72	Yes	10:1
Chest	Lateral	27–32	150	6		72	Yes	10:1
Chest	Lateral	33	150	8.33		72	Yes	10:1
Chest	Oblique	19–23	150	3		72	Yes	10:1
Chest	Oblique	24–30	150	5		72	Yes	10:1
Chest	Oblique	31–35	150	6.67		72	Yes	10:1

Ribs**	A.P.-P.A. A.D.	21–24	150	2.08		40	Yes	16:1
Ribs	A.P. B.D.	17–22	150	7.5		40	Yes	16:1

**Suspend respiration.

Pregnancy	A.P.	Average	150	7.5		40	Yes	16:1
Pregnancy	Lateral	34–38	150	12.5		40	Yes	16:1

All technical factors are based on the use of regular film and medium speed intensifying screens.
Radiation should be confined to an area no larger than the size of film.
To radiograph a part smaller than the indicated average centimeters – halve Ma.S.
To radiograph a part larger than the indicated average centimeters – double Ma.S.
Technical factors are based on 5 min. development at 68° in supermix chemicals. If 3 min. development is preferred, increase developer temperature to 75°.
Caution: Carefully observe tube rating chart when using 150 Kv.P.
Courtesy of X-ray Department, General Electric, Milwaukee 1, Wisconsin.

HIGH-KILOVOLTAGE AIR-GAP TECHNIQUE

It has been well established that the part to be radiographed should be as near to the film as possible in order to obtain sharpness in the radiographic image.

As stated previously, definition or detail is good or bad according to the contrast in the radiographic image. Contrast depends partly on the amount of scattered radiation reaching the film, and a means must be provided for reducing the scatter to the film. Scattered radiation can be reduced by cones, diaphragms, and grids. Scattered radiation can also be reduced by an air gap such as used in fractional-focus radiography. Watson has used an air-gap technique for radiography of the chest in large patients without a grid by increasing the part-film distance by six inches and employing a 10-foot focus-film distance. Figure 9.19 shows two radiographs of a chest measuring 27 cm. The radiograph on the left is at 80 Kv.P., 15 Ma.S., and 72-inch focus-film distance. The radiograph on the right is the same patient, but the film was exposed at 125 Kv.P., 5 Ma.S., 120-inch (10-foot) focus-film distance, and a 6-inch air-gap part-film distance.

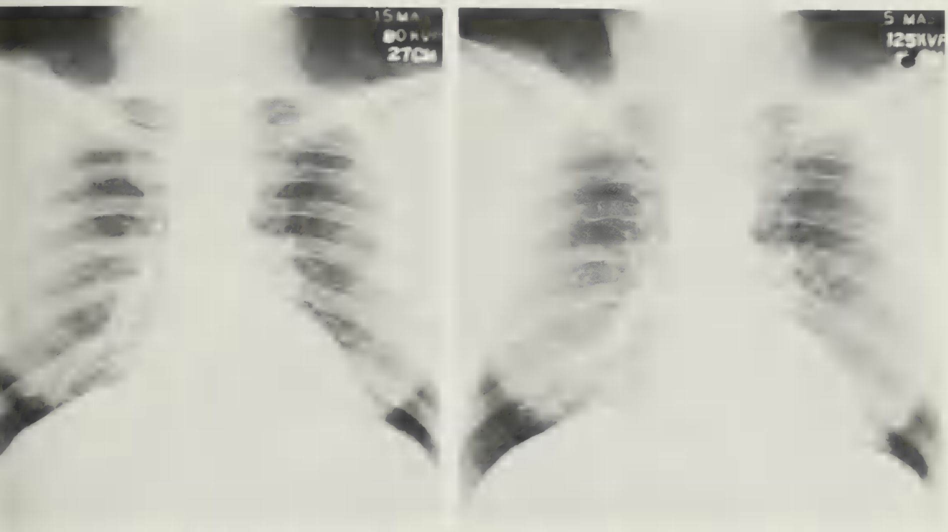


Figure 9.19. High kilovoltage air-gap technique; left, radiograph at 72 inches F.F.D.; right, at 120 inches F.F.D. with 6 inches part-to-film air gap.

Appendix. **X-RAY GENERATING APPARATUS**

The following is only a brief description of the generating apparatus needed in radiologic technology and is taken from *The Fundamentals of Radiography*, courtesy Eastman Kodak Co., Rochester, N.Y.

TRANSFORMER

A transformer is a device used to transfer alternating current electrical energy from one circuit to another and from one voltage level to another. In the simplest form, it consists of two coils of insulated wire wound on an iron core without having any electrical connection between them. The coil connected to the source of power is called the *primary* winding, the other the *secondary* winding. Voltage is *induced* in the secondary when energy is *applied* to the primary. The voltages in the two coils are directly proportional to the number of turns of wire in each—assuming a theoretical 100 per cent efficiency. For example, if the primary has relatively few turns, say 100, and the secondary has many, say 100,000, the voltage in the secondary is 1,000 times as high as that in the primary. At the same time, the current in the coils is decreased in the same proportion as the voltage is increased. In the example given, the current in the secondary is only $^1/_{1000}$ of that in the primary. A transformer of this type is used to supply the high voltage to the x-ray tube.

Autotransformer

The usual line voltage supplied for x-ray equipment is 220-volt alternating current. X-ray techniques, however, require a wide variety of kilovoltages. Therefore, the line voltage is adjusted by a special type of transformer—an autotransformer—so that the primary of the high-voltage transformer has a variable and predetermined supply. The result then is that the high voltage to the x-ray tube can be preselected at the autotransformer before the x-ray exposure is actually made. The device is called an autotransformer because the primary and secondary are combined in a single winding.

ACTION OF ALTERNATING CURRENT

A.c. voltage can be plotted in the form of a graph which represents the action of an imaginary voltmeter—if such a fast-acting one could be built—connected to the transformer terminals. When 60-cycle alternating current is used, the needle of the voltmeter would move from zero to a maximum (peak or crest) and back to zero again in $^1/_{120}$ second. It would immediately start off in the opposite or inverse direction, reach a peak, and return to zero in another $^1/_{120}$ second. This action is called a full cycle and requires $^1/_{60}$ second. Sixty of these cycles are accomplished in 1 second – hence the term "60-cycle a.c." For x-ray purposes, the tube voltage is almost always expressed in terms of the *peak* or *crest* value (which is abbreviated as Kv.P.). The x-ray tube receives a series of voltage pulses, one for each useful peak, and therefore produces x-rays in pulses or "bursts." In discussion involving alternating current in this book, a 60-cycle a.c. power supply will be assumed.

Self-rectification

When this a.c. voltage is applied directly to an x-ray tube (Figure A.1), the anode would be alternatively positive and negative with respect to the cathode during each half-cycle. When the anode is positive, the electrons available at the cathode are attracted to the anode, and x-rays are produced. Conversely, when the anode is negative, there is no attraction for the electrons. Hence, there is no current in the tube – no electron stream – and no x-radiation. This unused half-cycle is called the inverse voltage. Since the tube will produce x-rays every other half-cycle, that is, 60 pulses per second, it is called "self-rectifying." The system is practical in portable, bedside, and dental units.

Valve-tube rectification (half wave)

As it becomes necessary for x-ray tubes to carry more power, it is desirable to prevent them from operating as self-rectifiers and to find some means of preventing the inverse voltage from being applied to the x-ray tube. This is accomplished by introducing a valve tube into the high voltage circuit (see Figure A.2). The system is known as *half-wave rectification*.

A valve tube is similar to a stationary-anode x-ray tube but with two important differences. First, the filament is much larger and produces a superabundance of electrons. Second, these are not focused to a small spot on the anode but over the entire anode face. There is obviously no need for the anode face to be at an angle as in an x-ray tube; hence, it is constructed perpendicular to the electron stream. The valve tube anode does not become heated to the extent that the anode of an x-ray tube does because it absorbs very little power from the circuit compared to the x-ray tube.

Valve-tube rectification (full wave)

In order not to leave the inverse voltage unused, a very popular system is to insert four valve tubes in the circuit, as shown in Figure A.3 (top). In the first half cycle (center), a pair of the valve tubes (A-A_1) conducts the electron flow to the x-ray tube, while the corresponding pair is non-conducting. During the second half cycle, valve tubes B-B_1 complete the circuit. Thus, both half cycles are utilized and the voltage applied to the x-ray tube is at the rate of 120 pulses per second – all in the proper direction. This results in maximum efficiency of the equipment. The manner in which the full wave is employed is shown in the bottom diagrams, Figure A.3.

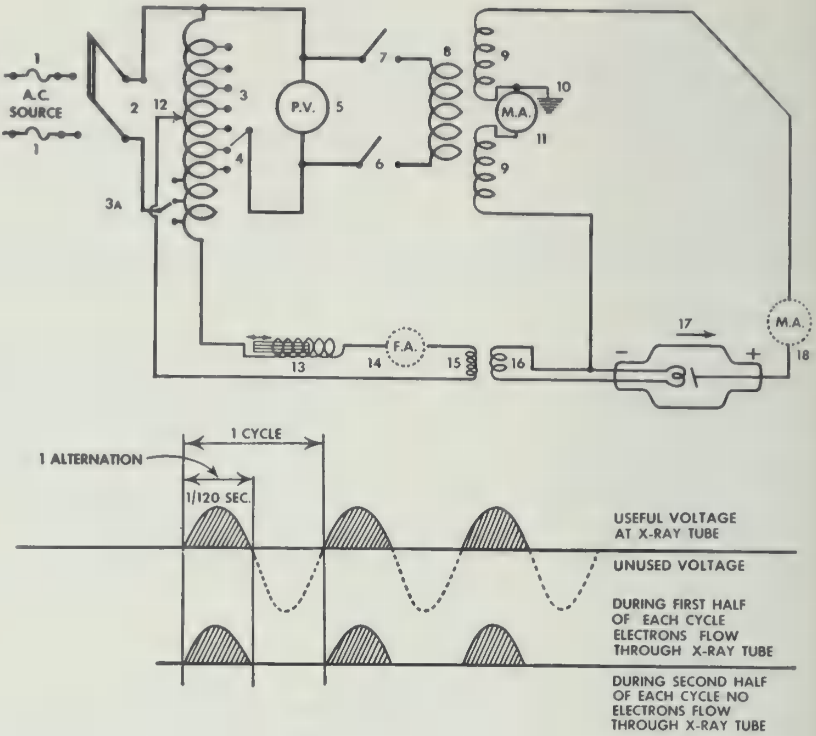

1
A.C.
SOURCE
1
2
12
3
3A
4
P.V.
5
7
6
8
9
10
M.A.
11
9
13
14
F.A.
15
16
17
−
+
M.A.
18
1 CYCLE
1 ALTERNATION
1/120 SEC.
USEFUL VOLTAGE AT X-RAY TUBE
UNUSED VOLTAGE
DURING FIRST HALF OF EACH CYCLE ELECTRONS FLOW THROUGH X-RAY TUBE
DURING SECOND HALF OF EACH CYCLE NO ELECTRONS FLOW THROUGH X-RAY TUBE

Figure A.1. Self-rectification.

LOW-VOLTAGE TRANSFORMER FOR FILAMENT

Some means must be furnished not only to light the filament of the x-ray tube but to control the degree of incandescence. The requirements for this are relatively few amperes at 4 to 12 volts, which are provided by a step-down or low-voltage transformer (15-16 in Figures A.1 to A.4). The secondary winding of the step-down transformer is very heavily insulated from the primary and the iron core in order that the high voltage applied to the x-ray tube shall not get back into the supply lines of the x-ray machine.

TRACING THE GENERATOR CIRCUIT

There are a number of other auxiliary devices that go to complete the x-ray generating apparatus, such as meters, fuses, and circuit breakers. They are shown in their proper places in the schematic drawing of the part of the circuit common to all x-ray generators (Figure A.4). Tracing the circuit will help to make clear the action of the various parts of the apparatus. Fuses (1) are placed in the incoming line as in all electrical apparatus. The current passes through the switch (2) to the autotransformer (3). A line voltage com-

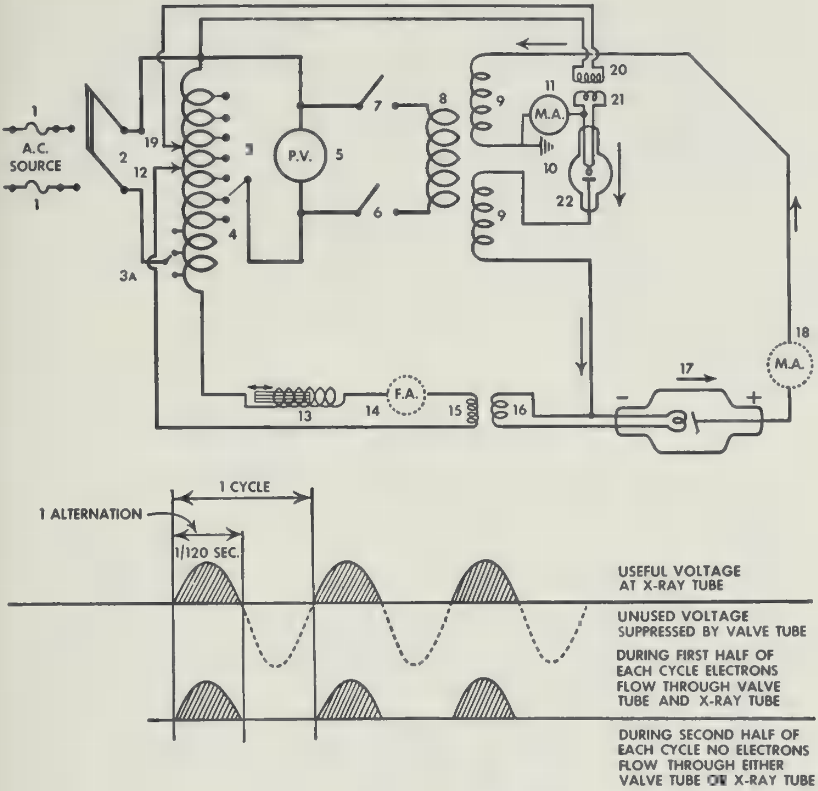

1
A.C. SOURCE
1
2
19
12
3A
3
4
P.V.
5
7
6
8
9
11
M.A.
10
9
20
21
22
13
14
F.A.
15
16
17
−
+
18
M.A.
1 CYCLE
1 ALTERNATION
1/120 SEC.
USEFUL VOLTAGE AT X-RAY TUBE
UNUSED VOLTAGE SUPPRESSED BY VALVE TUBE
DURING FIRST HALF OF EACH CYCLE ELECTRONS FLOW THROUGH VALVE TUBE AND X-RAY TUBE
DURING SECOND HALF OF EACH CYCLE NO ELECTRONS FLOW THROUGH EITHER VALVE TUBE OR X-RAY TUBE

Figure A.2. Half-wave rectification by means of a single valve tube.

LEGEND FOR CIRCUIT DIAGRAMS, FIGURES A.1 TO A.4

1. Fuses
2. Switch
3. Autotransformer

3A. Autotransformer line-voltage compensator

4. Autotransformer control
5. Prereading voltmeter
6. Circuit breaker
7. Automatic timer
8. Primary of high-voltage transformer
9. Secondary of high-voltage transformer
10. Ground
11. Milliammeter
12. Circuit connector for cathode filament
13. Voltage control for cathode filament with adjustable iron core
14. Ammeter for cathode filament
15. Primary of cathode-filament transformer
16. Secondary of cathode-filament transformer
17. X-ray tube
18. Milliammeter in high voltage circuit
19. Circuit connector for valve-tube filament
20. Primary of valve-tube filament transformer
21. Secondary of valve-tube filament transformer
22. Valve tube

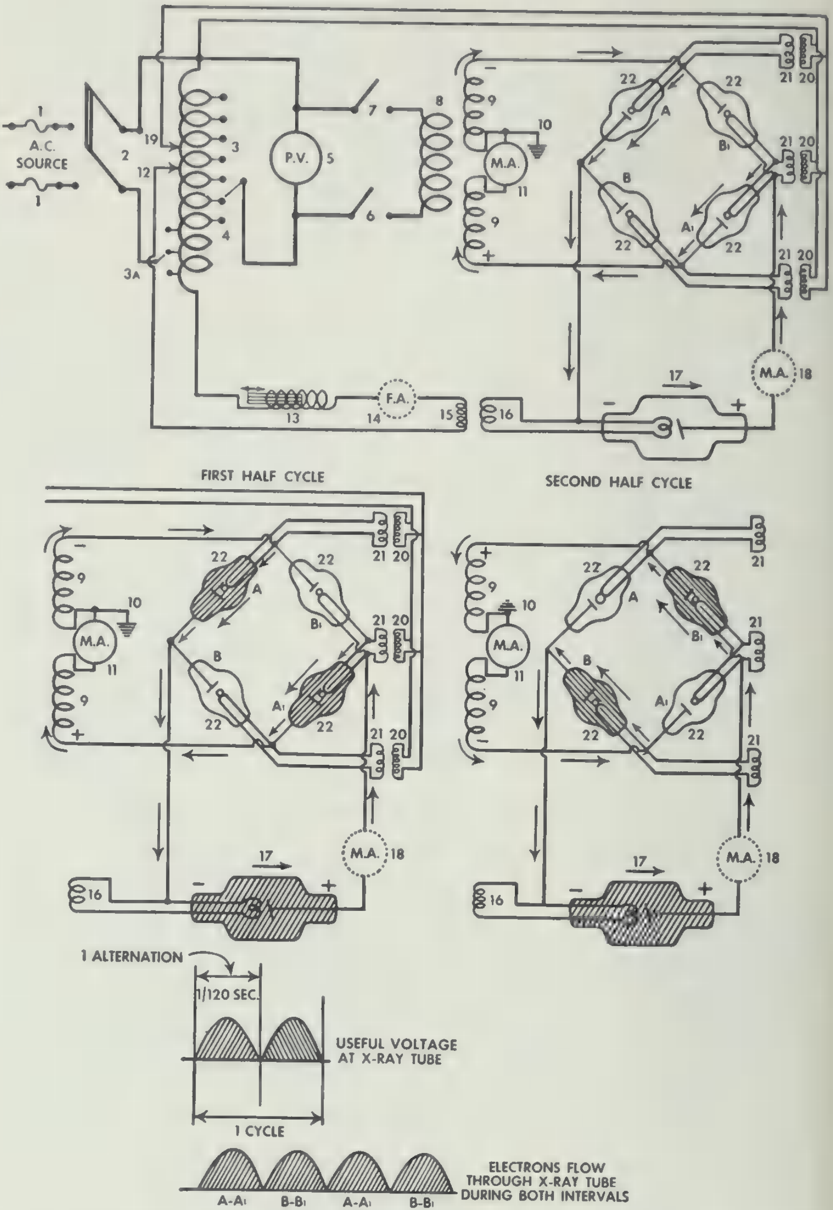


Figure A.3. Full-wave rectification by means of four valve tubes. Diagrams at center show action of the circuit during the first and second half-cycles.

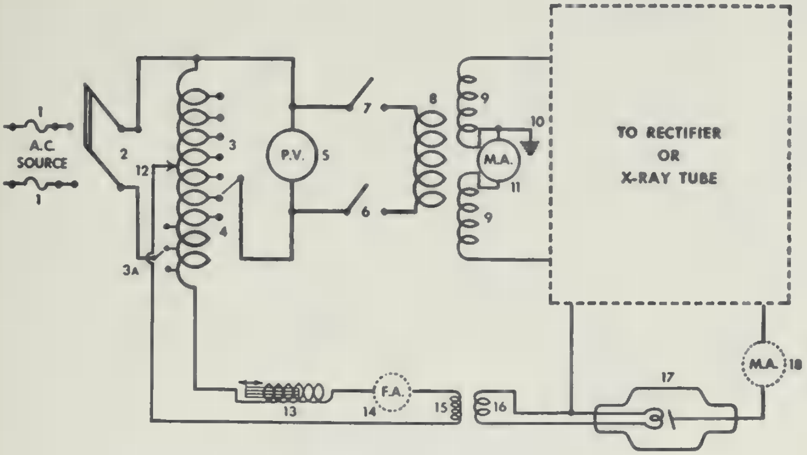


Figure A.4. Diagram of the portion of the electrical circuit which is common to all x-ray-generating apparatus.

pensator at 3A can be adjusted so that the correct input voltage is applied to the autotransformer. A prereading (a.c.) voltmeter (5) in the autotransformer circuit indicates the voltage applied to the primary (8) of the high-voltage transformer by means of the variable control (4). A circuit-breaker (6) acts when the high-voltage transformer is overloaded. A switch with automatic timer (7) is closed to make the x-ray exposure. The high-voltage x-ray tube current is indicated by the milliammeter (11).

The low-voltage transformer for the filament of the x-ray tube is supplied from a fixed position (12) on the autotransformer. An ammeter (14) permits the proper setting of the filament voltage control (13) for the transformer (15). The secondary of the filament transformer (16) is connected directly to the tube filament in the cathode of the x-ray tube (17).

The terminals of the secondary of the high-voltage transformer (9) are connected in various ways to the x-ray tube, depending on the rectification method. Modern equipment is so constructed that all parts exposed to high voltage are especially insulated. This includes the high-voltage transformer, the rectifier system, valve-tube and x-ray tube filament transformers, cables, and the x-ray tube. In older types of nonshockproof equipment, the high voltage is transmitted to the x-ray tube by exposed conductors, usually hung from the ceiling of the room by insulators. It is customary to place a high-voltage milliammeter (18) in this system.

Half-wave rectification requires the introduction of the valve tube (22) and its low-voltage filament transformer (20–21) as shown in Figure A.2 above. Full-wave rectification requires four properly connected valve tubes (22) and their appropriate low-voltage filament transformers (20–21) as shown in A.3 above. In either system, the low-voltage transformer for the valve-tube filament is supplied from a fixed connection on the autotransformer (19).

Table A.1 X-RAY UNIT TROUBLE SYMPTOMS

Symptoms	*Probable causes*	*What to do*
1. No x-ray (lights and meters on control do not indicate)	Line switch open	Check wall switch.
	Main fuse out	Have electrician check and replace fuse.
	Auxiliary fuse out in control	Same as above
2. No x-rays (lights and meters indicate but contactor does not close; no thump or noise in control)	Auxiliary fuse out in control	Same as above
	Timer motor not turned on	Check timer scale switch and setting.
	Timer set above safe exposure time (if equipped with safety limit switches)	Same as above
	Circuit breaker not pushed in	Check.
	Bucky not latched	Check and latch.
	Bucky electrical release defective	Set Bucky for longer time, attach string to manual release on Bucky, and release manually.
	Interlocking safety switches not properly set.	Recheck setting of all switches.
3. No x-ray (contactor closes but MA meter does not indicate)	Defective MA meter	Check for x-rays from tube by placing open cassette on table, darkening room and making exposure with tube directed toward screen. If no fluorescence is seen, follow checks below.
	X-ray tube filament not lighted	1. Check filament meter setting if there is one. 2. Observe tube filament through port with main switch on. 3. Check position of over-under table switch. 4. Check setting of focus selector switch if there is one. 5. Make sure that shockproof cables are properly attached at both x-ray tube and transformer.

Symptoms	Probable causes	What to do
		6. Flex cathode cable and observe tube filament with control turned on to check for broken lead in cable.
	KV selector on dead button or making poor contact	Check KV selectors and line compensation selector switch.
4. MA meter fluctuates	Loose connection of cathode cable either at x-ray tube or transformer	Check for loose connection of cable.
	Manual over-under table high tension switch making poor contact because of improperly meshed switch blades	Check and reset high-tension switch.
	Gassy x-ray tube Note: Slightly gassy x-ray tube can be operated at reduced MA temporarily, if MA meter holds constant at lower MA values.	Put mirror on table and direct x-ray tube toward it. Make exposure and watch for bluish-green fluorescence in x-ray tube.
	Varying power line. Observe KV line comp. and filament meters.	Consult power company and have one of its electricians make test with recording voltmeter.
	Improperly set focus switch if machine is equipped with one.	Check and reset switch.
5. MA meter indicates too low.	Improper filament setting	Check and reset switch.
	Valve filament burned out. Meter approx. ½ value	If machine is equipped with valve tube filament meter, find out what proper indication should be. Low (25%) filament amperes means burned out valve filament. If no valve-filament meter is provided but valve tubes can be observed, check that all are lighted. If one valve is out, consult x-ray tube rating chart. (Caution! Use half-wave or self-rectified ratings and operate at reduced MA until valve tube is replaced.)
	Poor connection of cathode cable at x-ray tube or transformer	Check connections at both ends of cathode cable and make sure that they are tight.

Symptoms	*Probable causes*	*What to do*
	Defective MA meter or wrong meter scale	Recheck filament setting and scale if provided with manual switch.
6. MA meter indicates too high.	Filament setting too high	Check and reset filament control.
	Wrong meter scale	Check position of MA meter scale, change switch if machine is so equipped.
	Gassy x-ray tube (meter flicks up)	Place mirror on table and direct x-ray tube toward it. it. Make exposure and watch for bluish green fluorescence in x-ray tube.
	Improper filament setting due to aging of x-ray tube	Reduce filament setting until proper MA is obtained.
7. Circuit breaker pops or jumps out and opens up exposure circuit.	Filament setting too high resulting in excessive MA	Recheck filament setting.
	KV set too high	Recheck setting.
	Punctured shockproof cable	Examine both shockproof cables carefully over entire length for any evidence or odor of burning.
	Gassy x-ray tube	Examine x-ray tube with mirror as described previously.
	Gassy valve tube	Call for service.
8. Inconsistent radiographic results	Error in setting of technical factors	Recheck settings for MA.-Kv. Exposure time, distance, use or non-use of cones, grids, filters, angulation of x-ray tube.
	Error in measurement or estimation of size of part to be examined	Remeasure patient, taking into consideration variations in patient types.
	Variations in film speeds	
	Variations in screen speeds (screen contact)	
	Failure to observe time and temperature development	
	Exhausted developing solutions	Change solutions frequently.
	Erratic exposure timer	Check with spin top.

Symptoms	*Probable causes*	*What to do*
	Line voltage variation	Observe all meters on control panel during day to check for variations.
	Poor connecting in filament circuit	Check connections at both ends of cathode cable to make sure they are right.
	Partial shockproof cable puncture	Observe MA meter during long exposure (2 to 3 sec.). If it fluctuates rapidly examine both shockproof cables carefully over entire length for any evidence or odor of burning.
9. Synchronous grid lines—handlatch Buckys	Bucky time dial set too long	Adjust Bucky time dial to slightly different setting.
	Bucky time dial set too short	Adjust Bucky time dial to slightly different setting.
	Exposure time too short	
	Air in Bucky timing device	Aim x-ray tube away from table, remove cassette tray, make long (2–3 sec.) Bucky exposure while holding hand on grid to check for smooth operation.
	Identification marker catching on grid	
10. Grid lines—reciprocating Buckys	Selected exposure times too close to initial travel time	
	Identification marker catching on grid	

Present generators and how they relate to radiographic quality

The most widely used type of generator operates on a single-phase power line. When provided with full-wave rectification, its kilovoltage output fluctuates between zero and a peak value in a manner that produces two impulses per cycle.

A second type of generator operates on a three-phase power line. It uses twelve rectifiers and a full-wave circuit, and produces a pattern of six impulses per cycle.

A third type of generator also operates on the three-phase power line, and it uses twelve rectifiers and a full-wave circuit, that produces a power of twelve impulses per cycle. With this type of rectification, the kilovoltage can be considered to be almost constant.

GENERAL QUESTIONS

1. When making films to be viewed in a standard stereoscope, the amount of shift required is determined by the
    - a. Focus-skin distance
    - b. Focus-film distance
    - c. Bucky-film distance
    - d. Object-film distance
2. Magnification can be decreased by
    - a. Increasing object-film distance
    - b. Decreasing object-film distance
    - c. Increasing Ma.S.
    - d. Decreasing focus-film distance
3. Poor screen contact results in
    - a. Half-moon shadows on the film
    - b. Black streaks on the film
    - c. Blurring of the radiographic image
    - d. Decreased time in the developer
4. The greatest density would be obtained by using
    - a. 25 Ma. and $^1/_{15}$ second
    - b. 50 Ma. and $^1/_{30}$ second
    - c. 100 Ma. and $^1/_{60}$ second
    - d. 10 Ma. and $^1/_{5}$ second
5. The quantity of x-rays is dependent upon
    - a. Kv.P.
    - b. Ma.S.
    - c. Ma.
    - d. Time
6. When going from an 8-to-1 grid to a 16-to-1 grid, you should increase the Kv.P. by
    - a. 4 Kv.P.
    - b. 6 Kv.P.
    - c. 12 Kv.P.
    - d. 16 Kv.P.
7. When a 16-to-1 grid is employed, the distance that should be used is
    - a. 36 inches
    - b. 48 inches

c. 40 inches
d. 72 inches

8. Artifacts on a finished radiograph result from
   a. Poor screen contact
   b. Rough handling of the film
   c. Insufficient Ma.S.
   d. Exhausted hypo

9. Which of the following directly influences the radiographic contrast?
   a. Ma.
   b. Ma.S.
   c. Kv.P.
   d. Time

10. Which of the following directly influences the radiographic density?
    a. Kv.P.
    b. Ma.
    c. Ma.S.
    d. Time

11. Which item below will increase the exposure to the patient's skin?
    a. Using the collimator
    b. 3 mm. of aluminum
    c. Low Kv.P. and High Ma.S.
    d. High Kv.P. and Low Ma.S.

12. Gamma radiation is measured by
    a. Voltmeter
    b. Ammeter
    c. Geiger counter
    d. Galvanometer

13. Which of the following would not require a sterile technique?
    a. Myelogram
    b. Urography
    c. Planogram
    d. Arteriogram

14. The quality of the x-ray beam is determined by
    a. The kilovoltage
    b. The Ma.S.
    c. The size of the focal spot
    d. The size of the target

15. A patient comes into your department with a foreign body of the abdomen. It would be better to
    a. Fluoroscope first
    b. Take a flat film of the abdomen first
    c. Operate first
    d. Put the patient to sleep first

16. Like poles of a magnet
    a. Repel each other
    b. Attract each other
    c. Do not affect each other
    d. Heat each other

17. When heat is applied to the filament of an x-ray tube
    a. Electrons are emitted
    b. X-rays are emitted
    c. Protons are emitted
    d. Neutrons are emitted

18. The time required to develop a film is dependent upon
    a. The amount of developer in the tank
    b. The size of the developing tank
    c. Temperature of the developer
    d. Temperature of the hypo

19. When doing a barium enema, the barium enema should always be
    a. At least 6 feet above the table
    b. At least 3 feet above the table
    c. At least 9 feet above the table
    d. At least 12 feet above the table

20. The Ma. for a routine fluoroscopy should be
    a. 0.2 to 0.4 Ma.
    b. 3 to 5 Ma.
    c. 10 to 20 Ma.
    d. 5 to 8 Ma.

21. An arthrogram might be a study of the
    a. Skull
    b. Kidneys
    c. Knee
    d. Eye

22. The primary purpose of a filter used in the diagnostic x-ray machine is
    a. To reduce contrast in the radiograph
    b. To reduce scattered radiation
    c. To reduce the skin dosage
    d. To increase the x-ray beam wave length

23. What is a *rad*?
    a. A unit of electrical pressure
    b. The basic measurement of radiation absorbed by living tissue
    c. A measurement of a designated portion of the primary x-ray beam
    d. A unit of electrical resistance

24. The chief advantage of high Kv.P. (over 100) in radiographs of heavy people is
    a. To reduce the exposure time
    b. To decrease latitude

c. To increase penetration
d. To improve contrast

25. Density in a radiograph is
a. Differences between the black and whites
b. Over-all blackness of the radiograph
c. The amount of distortion of the object
d. Clearness and sharpness of the image

26. What is a teleoroentgenogram?
a. A.P. view of the right hip
b. P.A. chest film taken at 72″ distance
c. Lateral view of the odontoid
d. Lateral view of the chest at 36″ distance

27. Which of the following is not a portion of the colon?
a. Cecum
b. Transverse colon
c. Sigmoid
d. Ilium

28. Which of the following terms is not used to measure radiation?
a. Rads
b. Milliroentgen
c. Milliamperes
d. Roentgen

29. Name the tissue that is more sensitive to radiation
a. Brain
b. Skin
c. Muscle
d. Gonads

30. The primary function of Ma.S. is to
a. Increase detail
b. Increase penetration
c. Improve contrast
d. Regulate density

31. Long exposures are used to the best advantage during an examination of the
a. Chest and heart
b. A.P. abdomen
c. Lateral cervical spine
d. Lateral dorsal spine

32. In the A.P. projection of the lumbar-sacral articulation, the central ray is projected
a. Caudad 10°
b. Caudad 15° to 35°
c. Cephalad 15° to 35°
d. Cephalad 5°

33. In the P.A. Caldwell projection of the frontal sinuses, the central ray is angled caudad
    - a. 10°
    - b. 15°
    - c. 23°
    - d. 30°

34. In order to flatten and straighten the spine, an A.P. projection of the lumbar-sacral spine is taken with
    - a. The knees and feet together
    - b. The knees flexed and feet flat on the table
    - c. The knees extended and toes internally rotated
    - d. The patient sitting up

35. Elon has what function in the developer?
    - a. As preserver
    - b. As restrainer
    - c. As alkali or activator
    - d. As developing or reducing agent

36. Potassium bromide has what function in the developer?
    - a. Fixing
    - b. Washing
    - c. Restraining
    - d. Activating

37. What is the optimum time-temperature for the development of maximum contrast in the radiograph?
    - a. 3 minutes at 68°
    - b. 4 minutes at 63°
    - c. 5 minutes at 68°
    - d. 6 minutes at 69°

38. What type of filter is used over the safelights in the darkroom?
    - a. Wratten 5-B
    - b. Wratten 10-B
    - c. Wratten 6-B
    - d. Bratten 6-B

39. What is the purpose of potassium alum in the fixer solution?
    - a. To acidify the solution
    - b. To preserve the film
    - c. To fix the film
    - d. To harden the film

40. How often should you change the developer?
    - a. When you are told to do so
    - b. When you run out of replenisher
    - c. When fixation occurs
    - d. When oxidation occurs

41. Chemical fog is caused by
    - a. Overexposure to x-rays
    - b. Light leaks
    - c. Aged developer
    - d. Improper coning

42. Stains on intensifying screens caused by darkroom chemicals
    - a. Will have no effect on the finished radiograph
    - b. Will cause light spots on the finished radiograph
    - c. Will cause black spots on the finished radiograph
    - d. Will not affect the quality of the intensifying screens

43. What is the purpose of the stop bath?
    - a. To activate the developer
    - b. To stop the developing process
    - c. To add acetic acid to the fixer
    - d. To preserve the film

44. A grayish yellowish strip at one end of the film is caused by
    - a. High developing level
    - b. High hypo level
    - c. Low developing level
    - d. Low hypo level

45. Small white marks on the finished radiograph may be caused by
    - a. Static because of impact
    - b. Dirty cassettes
    - c. Inadequate washing after hypo
    - d. Hot solutions

46. A strip of transparent film at one end of the film is caused by
    - a. Low hypo
    - b. Low hypo and high developer
    - c. High hypo and low developer
    - d. Low hypo and low developer

47. Transfer of image from one film to another is caused by
    - a. Old developer
    - b. Excessive heating of wet emulsion during processed drying
    - c. Slight contact of emulsion surfaces of two films in the developer
    - d. Slight contact of emulsion surfaces of two films in the hypo

48. Excessive density throughout the finished radiograph is caused by
    - a. Underexposure
    - b. Overexposure
    - c. Cold solution
    - d. Defective screens

49. The current flowing between the transformer and the rectifier is
    - a. Direct current
    - b. Alternating current

c. Pulsating current
d. High-frequency current

50. Electrical pressure, or potential difference, is measured in
a. Amperes
b. Volts
c. Watts
d. Ohms

51. X-rays travel at a speed of
a. 189,000 miles per hour
b. 186,000 miles per second
c. 198,000 miles per second
d. 186,000 miles per hour

52. If one is checking the timer of a full-wave rectified x-ray machine, the number of dots recorded on the film should be as follows:

a. At $^1/_{10}$ of a second:
6
12
3
16

b. At $^1/_{60}$ of a second:
2
4
6
8

c. At $^1/_{30}$ of a second:
2
4
5
6

d. At $^1/_{20}$ of a second:
2
3
6
4

e. At $^1/_{120}$ of a second:
2
1
3
4

53. The safe tolerance amount of whole-body radiation per week is about
a. 0.6 r
b. 3.0 r
c. .001 r
d. 0.3 r

54. The acetabulum is
a. The socket for the malleolus
b. The groove for the optic nerve
c. Housing for the pituitary gland
d. The socket for the hip

55. What is the atlas?
a. 5th L.S. spine
b. 1st dorsal spine

c. 1st cervical spine
d. 5th dorsal spine

56. The semicircular canal is located

a. In the external auditory meatus
b. In the internal auditory meatus
c. In the frontal portion of the skull
d. In the maxillary sinuses

57. The lordotic view of the chest is used to demonstrate the

a. Heart
b. Apex
c. Ribs
d. Diaphragm

58. To judge if your position is correct in the mentovertex view of the skull, on the radiograph you should visualize the

a. Foramen magnum
b. Optic foramen
c. Foramen ovale
d. Sphenoid sinuses

59. Under 100 Kv.P., the percentage of energy in the cathode stream which is converted into x-rays is

a. 60 to 100 per cent
b. Less than 1 per cent
c. 10 per cent
d. 3 to 5 per cent

60. A good insulator is

a. Aluminum
b. Tin
c. Water
d. Oil

61. Following development, the film should be placed in a stop bath for at least

a. 2 minutes
b. 3 minutes
c. 1 minute
d. ½ minute

62. The emulsion on an x-ray film consists of

a. Silver nitrate and cellulose
b. Silver bromide and gelatin
c. Silver nitrate and gelatin
d. Cellulose and acetate

63. The fixed-voltage technique uses

a. Fixed Kv.P. and varied Ma.S.

b. Fixed Ma.S. and varied Kv.P.
c. Fixed Kv.P. and fixed Ma.S.
d. Varied Ma.S. and varied Kv.P.

64. Which of the following materials is not generally used in x-ray-therapy filters

a. Aluminum
b. Tin
c. Copper
d. Brass

65. The purpose of the filter used in x-ray therapy is to

a. Change the quality of radiation
b. Limit the area of exposure
c. Increase the average wave length
d. Increase the amount of radiation

66. The total amount of filtration (including inherent filtration) for the average diagnostic machine is

a. 1.5 mm. of Al.
b. 4.2 mm. of Al.
c. 3.5 mm. of Al.
d. 2.5 mm. of Al.

67. Lighting speed screens are made with

a. Small crystals
b. No crystals
c. Large crystals
d. Silver bromide

68. In making a P.A. radiograph of the wrist, the hand should be placed in

a. Supination
b. Flexion
c. Pronation
d. Extension

69. Rotation of the body in positioning for a radiograph is primarily to overcome

a. Superimposition
b. Magnification
c. Motion
d. Discomfort

70. The primary purpose of a KUB is to show

a. The urogenital diaphragms, kidneys, and ureters
b. Bladder, ureters, and kidneys
c. Pelvis, femur, and bladder
d. Chest, diaphragm, and kidneys

71. Match the prefix with the meaning

Retro- a. Above
Dys- b. After

Hyper-
Peri-
Hypo-
Macro-
Semi-
Trans-
Uni-

c. Through
d. Under
e. Large
f. Behind
g. Across
h. One
i. Half
j. Around
k. Difficult

72. Match the landmark to the part

Glenoid cavity
Radius
Styloid process
Navicular
Innominate bone
Patella
Medial malleolus
Cuboid
Foramen magnum
Lamina

a. Shoulder
b. Scapula
c. Elbow
d. Forearm
e. Ulna
f. Mandible
g. Ankle
h. Skull
i. Pelvis
j. Foot
k. Knee
l. Wrist
m. Lumbar spine

73. Match the meanings:

Arthritis
Carcinoma
Bursitis
Dermatitis
Sinusitis
Mastoiditis
Osteoma
-oma
-osis
Ostitis

a. Inflammation of the mastoid
b. Inflammation of the skin
c. Cancer
d. Tumor of bone
e. Inflammation of bone
f. A piece of dead bone
g. A tear
h. Inflammation of a joint
i. Condition or state
j. Tumor
k. Inflammation of a bursa
l. Inflammation of the paranasal sinuses

74. The left side of the brain controls the

a. Left side of the body
b. Neither side of the body
c. Right side of the body
d. Both sides of the body

75. The cystic duct is associated with the

a. Kidney
b. Colon
c. Heart
d. Gallbladder

76. Match the name of the study with the part:

I.V. cholangiogram
Bronchogram
Salpingogram
Ventriculogram
Venogram
Angiocardiogram
Cerebral arteriogram
Sialogram

a. Heart
b. Cystic duct
c. Bronchial tree
d. Gallbladder
e. Parotid glands
f. Veins of legs
g. Abdominal aorta
h. Urinary tract
i. Colon
j. Uterus and tubes
k. P.A. chest film
l. Fluid-containing space of brain
m. Arteries of the brain

77. When necessary, you can decrease your time by one-half if you increase your Kv.P. by

a. 20 per cent
b. 15 per cent
c. 10 per cent
d. 5 per cent

78. You cannot use planography to its best advantage for

a. The skull
b. The L.S. spine
c. The finger
d. The chest

79. Magnification distortion is used to advantage in making good radiographs of the

a. Femoral neck
b. Gallbladder
c. Heart
d. T.M. joints

80. In the examination of the gallbladder, a lateral decubitus view is usually taken to show

a. Mobility of gallbladder
b. Layering of gallstones
c. Dye content of the stones
d. Increased density of the gallbladder

81. In the P.A. projection of the chest, the shoulders are rolled forward to

a. Raise the diaphragm
b. Decrease part-film distance
c. Give true heart size
d. Remove the scapulae from the lung field

82. X-rays were discovered in

a. 1795

b. 1895
c. 1869
d. 1902

83. The father of x-rays was
    a. Coolidge
    b. Fuchs
    c. Whithead
    d. Roentgen

84. The first vacuum tube was made by
    a. Coolidge
    b. Crooks
    c. Roentgen
    d. Hudson

85. In order to make any visible change in a radiograph using the fixed-voltage technique you have to increase
    a. 20 Kv.P.
    b. 5 Kv.P.
    c. 10 Kv.P.
    d. 15 Kv.P.

86. High Kv.P. results in
    a. Long wave lengths
    b. Short wave lengths
    c. No wave lengths
    d. Short and long wave lengths

87. Long wave lengths result in
    a. Short scale contrast
    b. Ma.S.
    c. Long scale contrast
    d. No contrast

88. Dental films are available in several sizes, including
    a. Proximal
    b. Periapical
    c. Komberg
    d. Bite-wing

89. The compound most commonly employed in intensifying screens is
    a. Calcium carbonate
    b. Silver bromide
    c. Sodium carbonate
    d. Calcium tungstate

90. Continued fluorescence of a screen after exposure is called
    a. Bucking
    b. Warping
    c. Lag
    d. Large crystals

91. The exposure timer cord on a bedside unit should be at least
    a. 2 feet long
    b. 4 feet long
    c. 6 feet long
    d. 8 feet long

92. The amount of radiation received by the patient and the technologist is greatest in
    a. A radiograph of the wrist
    b. A barium enema using 2 minutes fluoro
    c. A P.A. chest taken at 72 inches
    d. A radiograph of the L.S. spine

93. The sharpness of detail of a thin part is increased by the use of
    a. No screens
    b. High-speed screens
    c. High-speed film
    d. A collimator

94. The sharpness of detail in a radiograph is decreased by the use of
    a. A grid
    b. A decrease of 10 Kv.P.
    c. A large focal spot
    d. Increased Ma.S.

95. The following disease is always hard to penetrate:
    a. Carcinoma
    b. Hyperparathyroidism
    c. Paget's disease
    d. Emphysema

96. The structures not shown in a P.A. of the wrist are the
    a. Radial and ulnar styloid process
    b. Metatarsal bones
    c. Metacarpal bones
    d. Navicular

97. In the following, check the items which you believe demonstrate a fracture of the external malleolus:

A. Part to be radiographed:
1. Foot
2. Knee
3. Hip
4. Ankle

B. Central ray directed to the:
1. Foot
2. Knee
3. Ankle
4. Hip

C. Position of the part:
1. Standing
2. Prone
3. Supine
4. Lateral

D. Accessories to be used:
1. Screens
2. Screens and grid
3. Potter Bucky
4. Cone

98. The ideal views to demonstrate a fracture of the metatarsal bones are
   a. Lateral and P.A.
   b. Standing A.P.
   c. A.P., lateral and oblique
   d. Lateral and oblique

99. The radiographs which may be taken to demonstrate free air in the peritoneal cavity are the:
   a. A.P. upright
   b. Lateral decubitus
   c. A.P. supine
   d. Transabdominal

100. In the lateral projection of the wrist, it is important to
   a. Pronate the wrist 15°
   b. Flex the fingers
   c. Extend the hand
   d. Superimpose the radius and ulna

101. Indicate which of the following is located in the right upper quadrant of the abdomen:
   a. Spleen
   b. Appendix
   c. Hepatic flexure
   d. Descending colon

102. Indicate which of the following is not located in the pelvic area:
   a. Ovaries
   b. Sigmoid
   c. Kidneys
   d. Rectum

103. Which of the following is not used for an anatomical reference point?
   a. Iliac crest
   b. Symphysis pubis
   c. Umbilicus
   d. Suprasternal notch

104. Beta rays consist of high-speed
   a. Neutrons
   b. Electrons
   c. Protons
   d. Atoms

105. In order to show the nasopharynx to its best advantage, we would take a lateral radiograph of the
   a. Chest
   b. Cervical spine
   c. Lateral skull, slow inspiration
   d. Soft tissue of cervical spine

106. Medical x-ray film should be kept in a
    a. Wet, cool place
    b. Dry, cool place
    c. Hot, wet place
    d. Hot, dry place

107. In an illuminator the following type of bulb should be used:
    a. 15-watt, daylight-type bulb
    b. 20-watt, incandescent
    c. 100-watt, daylight-type bulb
    d. Any type you have

108. When a cylinder cone is employed, all other factors the same, Kv.P. should be increased
    a. 10 Kv.P.
    b. 15 Kv.P.
    c. 25 Kv.P.
    d. 5 Kv.P.

109. A grid ratio is determined by the relationship of the
    a. Length to the width of the strips
    b. The width to the space
    c. The height to the width of the strip
    d. None of the above

110. The cushion between vertebrae is called the
    a. Intervertebral disc
    b. Spinous process
    c. Transverse process
    d. Intervertebral foramina

111. The coccyx is composed of
    a. 12 vertebrae
    b. 4 fused vertebrae
    c. 8 well-developed vertebrae
    d. None of the above

112. The xiphoid process is located in the
    a. Pelvis
    b. Abdomen
    c. Sternum
    d. Shoulder

113. Loss of the ability to smell most commonly occurs when there is an abnormality of the
    a. Nose
    b. Frontal bone
    c. Cribriform
    d. Zygomatic process

114. The alveolar border is located in the:
    a. Foot
    b. Temporal bone
    c. Parietal bone
    d. Mandible

115. The crista galli is found in the
    a. Sphenoid bone
    b. Ethmoid bone
    c. Hard palate
    d. None of the above

116. The following is not found in the structure of a healthy tooth:
    a. Crown
    b. Root
    c. Neck
    d. Cavity

117. If you took a film of the bicipital groove, you would have a radiograph of the
    a. Skull
    b. Elbow
    c. Humerus
    d. Foot

118. The two large soft spots at the top of a child's skull at birth are called
    a. Parietals
    b. Lambdoidals
    c. Coronal sutures
    d. Fontanelles

119. In viewing a flat film of the abdomen, the muscle usually visualized is the
    a. Psoas muscle
    b. Deltoid muscle
    c. Triceps muscle
    d. None of the above

120. In the lateral projection of the skull, the interpupillary line is
    a. Angled 5° to the film
    b. Perpendicular to the film
    c. Parallel to the film
    d. None of the above

121. The flow of electricity is
    a. From negative to positive
    b. From positive to negative
    c. 151,000 miles per hour
    d. None of the above

122. Match the following:

Stat.
NPO
CR
FFD
SWG
Kv.P
16-to-1

a. Cardboard
b. Focal film distance
c. Kilovoltage
d. Grid
e. Central ray
f. Screens with grid
g. Nothing by mouth
h. Rush

123. The orbital-meatal line for the Waters view is at

a. 20°
b. 37°
c. 23°
d. 30°

124. The epidermis is the name of

a. The inner layer of skin
b. The outer layer of skin
c. Sweat glands
d. None of the above

125. Match the following:

Anterior
Superior
Internal
External
Posterior
Proximal

a. Upper
b. Lower
c. Front
d. Back
e. Close to
f. Away from
g. Inside
h. Outside

126. The type of glass used on an illuminator is

a. Clear glass
b. Tinted glass
c. White opal glass
d. None of the above

127. In radiography of the L.S. spine for a disc, prior to the myelogram, the views normally taken are

a. A.P.
b. Obliques
c. Lateral
d. All of the above

128. Complete the following sentences:

a. The front of a cassette is made of ________.
b. The light from intensifying screens is ________ in color.
c. The light from a fluoroscopic screen is ________ in color.

d. The type of film that cannot be used with automatic processing is ______.

e. The optimum developing time for hand processing is ______° for ______ minutes.

f. Intensifying screens are made of ______.

g. Fluoroscopic screens are made of ______.

h. Non-screen film is used for ______ parts.

i. Screen "afterglow" is called ______.

j. Poor screen contact results in ______ of the radiographic image.

129. Define:

a. Medial
b. Lateral
c. Anterior
d. Posterior
e. Superior
f. Inferior
g. Proximal
h. Distal
i. Cephalic
j. Caudad
k. Plantar
l. Supine
m. Prone
n. Flex
o. Extend

130. Name the bones comprised in the knee joint.
131. Name the bones of the cranium.
132. How many pairs of ribs are there?
133. What is the acetabulum?
134. What is a sesamoid bone?
135. Name the sections of the spine and the number of vertebra in each.
136. Draw and label the colon.
137. Name the main divisions of the urinary tract.
138. What are the fingers and toes called?
139. Where is the gallbladder located?
140. What joint do the carpals form?
141. What joint do the tarsals form?
142. In what bone are the mastoid cells found?
143. Where is the occipital protuberance?
144. Name the nasal accessory sinuses.

145. Match the following:

Manubrium
Atlas
Malleolus
Glenoid fossa
Metacarpals
Ileum
Os calcis
Patella
Symphysis pubis
Olecranon process

a. Ankle
b. Hand
c. Pelvis
d. Shoulder
e. Sternum
f. Cervical
g. Knee
h. Hip
i. Foot
j. Small bowel
k. Sphenoid
l. Elbow

146. Draw and label the parts of the stomach.
147. Define the following:
    a. Median plane
    b. Saggital plane
    c. Canthomeatal line
    d. Acanthiomeatal line
    e. Interpupillary line
148. The clavicle articulates with the ______ and ______.
149. The bones of the forearm are ______ and ______.
150. The bones of the lower leg are the ______ and the ______.
151. The styloid process is part of the ______ bone (skull).
152. The term vertex refers to the ______ portion of the skull.
153. The appendix is connected to the ______.
154. Where is the glabella?
155. Where is the xiphoid process?
156. To what joints is the navicular related?
157. Name the four quadrants of the abdomen.
158. Where are the kidneys located?
159. The olecranon is related to what joint?
160. Match:

Acromion
Coronoid process
Petrous
Gallbladder
Lacrimal
Sphenoid

a. Liver
b. Temporal
c. Facial bone
d. Spleen
e. Scapula
f. Mandible
g. Ischium
h. Sella turcica

161. To what do the following terms refer:
    a. Cephalic
    b. Extrinsic
    c. Adduction
    d. Abduction
162. Define the following prefixes:
    a. anti-
    b. hypo-
    c. intra-
    d. sub-
    e. supra-
    f. median-
    g. lateral
    h. antero-
    i. postero-
163. Name nine systems of the human body.
164. Define *articulation*, *lumen*, *shaft*, *sinus*, and *symphysis*.
165. What system is the periosteum in?
166. In what extremity is the metacarpal?
167. Where is the talus? The calcaneus? Tibia? Navicular? Scapula? Patella?
168. Where is a disc found?
169. Where is the suprasternal notch?
170. Where is the zygomatic bone?
171. Where is the mastoid process?
172. Where is the mediastinum?
173. What does auditory refer to?

General Questions

174. How many chambers does the normal heart have? Name them.
175. What is the function of a vein?
176. What does the biliary system carry?
177. Name two ways in which the biliary tract can be visualized.
178. What passes through the foramen magnum?
179. In order to show the forearm in the lateral projection, the elbow is flexed at ________° and the thumb must be in the ________ position.
180. In order to show the coronoid process of the elbow, free of superimposition, we must have the elbow in the ________ position.
181. With the elbow in acute flexion, we normally would be showing a clear view of the ________ process.
182. In the medial oblique position of the foot, we rotate the leg medially until the sole of the foot forms an angle of approximately ________° to the plane of the film.
183. In the plantardorsal projection of the os calcis, the patient is in which of the following positions: supine, prone, lateral, or standing?
184. If we were to take a radiograph of the bicipital groove, we would be making a radiograph of the ________.
185. In order to show the lateral thoracic spine to its best advantage, we would use a ________, ________ technique.
186. In the A.P. radiograph of the lumbar spine, the knees and feet are in what position? ________
187. For scoliosis we normally would take an A.P. projection in the ________ position and include from the ________ to the third or fourth thoracic vertebra.
188. In the A.P. projection of the sacrum the central ray is directed approximately ________° towards the ________.
189. In the anteroposterior projection of the coccyx we would normally direct the central ray ________° towards the ________.
190. If you were asked to show the anterior and posterior clinoid processes, you would normally take a radiograph in the lateral projection of the ________.
191. In radiography of the lumbar spine for a possible disc prior to a myelogram study, what three views would we normally take?
192. In the case of spondylolisthesis, we would normally take a spot film of ________.
193. In order to show the nasopharynx to its best advantage we would normally take a lateral radiograph of the ________ on ________.
194. In order to show the abdominal aorta we would normally take a ________ position of the ________.
195. Indicate in the right-hand column whether presence of the pathological state listed on the left makes the part being radiographed easy to penetrate or hard to penetrate.

Pathology	*Easy to penetrate*	*Hard to penetrate*
Emphysema		
Arthritis		
Hydrocephalus		
Osteoporosis		
Atrophy		

196. An x-ray technique from Hospital A for the A.P. skull calls for 85 Kv.P., 20 Ma.S., 36-inch focus-film distance, medium screens, 8-to-1 grid. It is desired to adapt this technique to your hospital. What procedure would you follow in making this technique work in your department?

197. When secondary radiation and Ma.S. are controlled, kilovoltage becomes a factor of radiographic ____.

198. Exposure latitude is the range between ____ exposure and ____ exposure that can be used to produce a diagnostically acceptable radiograph.

199. Great exposure latitude can be secured by using higher kilovoltage. It also can be secured by the use of ____ and ____ film.

200. The only limit to the kilovoltage that can be used in radiography is the limitation imposed by ____.

201. If you are using a technique at 60 Kv.P. and wish to cut the time in half, how much kilovoltage do you add?

202. The principal factor in controlling the penetration of x-rays is ____.

203. The principal factor in controlling density is ____.

204. The wave length of an x-ray beam is determined by ____.

205. The quantity of x-rays received at a given point is primarily dependent on ____.

206. What factors in an x-ray exposure must be changed to produce increased density?

207. Magnification in a radiograph can be lessened by the use of ____.

208. Cones, stationary grids, and Bucky diaphragms are similar in that their primary function is to ____.

209. The grid ratio of the Potter Bucky diaphragm is the ratio of the ____ of the lead strips to the ____ between the strips.

210. The two types of stationary grids used today are referred to as a ____ grid and a ____ grid.

Fill in the following:

211. Kilovoltage
   a. regulates ____.
   b. determines the degree of ____.
   c. influences the production of ____.
   d. regulates the scale of radiographic ____.
   e. determines the degree of exposure ____.
   f. influences radiographic ____.

212. Focus-film distance
   a. influences the ____ and ____ of the radiographic image.
   b. influences radiographic ____.

213. Milliampere seconds
   a. regulate the ____ of x-radiation admitted by the x-ray tube.
   b. regulate radiographic ____.

214. Formulate a typical technique for radiography of the skull with

a. Variable kilovoltage technique, centimeter part thickness
b. Fixed kilovoltage technique
c. High-kilovoltage technique

215. Define:

EMF
Potential
HVL
FFD
Ohm
Ampere
Volt
Kilovolt

216. Intensity of electricity is measured in (circle one):

Kv.P. Watts Amperage Volts Ohms

217. The flow of electricity is from ______ to ______.
218. Atoms are composed of ______, ______, and ______.
219. The three basic requirements for the production of x-rays are ______.
220. The current flowing between the transformer and the rectifier is ______.
221. The quantity of electrons in the cathode stream is dependent directly on ______.
222. What is the real advantage of a rotating-anode tube?
223. What portion of the total energy delivered to an x-ray tube at the target is given off as x-rays?
224. What is meant by hard rays? Soft rays?

ANSWERS FOR GENERAL QUESTIONS

1. b **2.** b **3.** c **4.** d **5.** b **6.** b **7.** c **8.** b **9.** c **10.** c **11.** c **12.** c **13.** c **14.** a **15.** b **16.** a **17.** a **18.** c **19.** b **20.** b **21.** c **22.** c **23.** b **24.** a **25.** b **26.** b **27.** d **28.** c **29.** d **30.** d **31.** d **32.** c **33.** c **34.** b **35.** d **36.** c **37.** c **38.** c **39.** d **40.** d **41.** c **42.** b **43.** b **44.** d **45.** b **46.** c **47.** c **48.** b **49.** b **50.** b

51. b **52.** a. 12, b. 2, c. 4, d. 6, e. 1 **53.** d **54.** d **55.** c **56.** b **57.** b **58.** c **59.** b **60.** d **61.** d **62.** b **63.** a **64.** d **65.** a **66.** d **67.** c **68.** c **69.** a **70.** b **71.** f, k, a, j, d, e, i, g, h **72.** a, d, e or h, l, i, k, g, j, h, m **73.** h, c, k, b, l, a, d, j, i, e **74.** c **75.** d **76.** b, c, j, l, f, a, m, e **77.** b **78.** c **79.** d **80.** b **81.** d **82.** b **83.** d **84.** b **85.** b **86.** b **87.** a **88.** b **89.** d **90.** c **91.** c **92.** b **93.** a **94.** c **95.** c **96.** b **97.** A4; B3; C4; D1 and D4 **98.** c **99.** a, b, and d **100.** d

101. c **102.** c **103.** c **104.** b **105.** c **106.** b **107.** b **108.** d **109.** d **110.** a **111.** b **112.** c **113.** c **114.** d **115.** b **116.** d **117.** c **118.** d **119.** a **120.** b **121.** a **122.** h, g, e, b, f, c, d **123.** b **124.** b **125.** c, a, g, h, d, e **126.** c **127.** d

128. a. Radiolucent material, such as Bakelite or Magnelite; b. Blue; c. Greenish-yellow; d. Non-screen film; e. 68° for 5 minutes; f. Calcium tungstate; g. Zinc cadmium sulfide; h. Small (less than 12 cm); i. Lag; j. Blurring.

129. a. Close to the median line or center; b. Away from the median line of the body; c. Towards the front; d. Towards the back; e. The upper part or nearer the head; f. The lower part or away from the head; g. Closest to the point of origin; h. Farthest from the point of origin; i. Of the head; j. Towards the tail end; k. Of the sole of the foot; l. Lying on the back; m. Lying face down; n. To bend; o. To straighten **130.** The distal femur and the proximal tibia **131.** *Cerebral cranium:* frontal (1), parietal (2), occipital (1), temporal (2), sphenoid (1), ethmoid (1); *Visceral cranium:* maxilla (2), zygomatic (2), nasal (2), lacrimal (2), palatine (2), turbinate (2), vomer (1), mandible (1) **132.** 12 pairs **133.** The socket at the junction of the three parts of the innominate bone which accommodates the head of the femur to form the hip joint **134.** One of the small accessory bones located in the tendons, usually at joints and bony prominences **135.** Cervical spine (7), thoracic spine (12), lumbar spine (5), sacrum (5 fused), and coccyx (4 fused) **136.** Cecum, ascending colon, hepatic flexure, transverse colon, splenic flexure, descending colon, sigmoid, rectum, anus.

137. Kidneys, ureters, bladder, urethra **138.** Phalanges **139.** In the upper right quadrant of the abdomen, usually opposite the ninth costal cartilage

140. The intercarpal joint of the wrist **141.** The intertarsal joint of the foot **142.** The temporal bone **143.** On the squamous part of the occipital bone, in the midline, where it helps to form the base of the skull **144.** Frontal, sphenoid, ethmoid, and maxillary **145.** e, f, a, d, b, j, i, g, c, l **146.** Fundus, body, pylorus, duodenum, greater and lesser curvatures.

147. a. A plane through the median line of the body as if a cut were made from front to back through the sagittal suture of the skull and continued down through the body, dividing it into equal parts. The view is of one cut surface. b. Any plane parallel to or in the same direction as the median plane. c. An imaginary line connecting the outer canthus of the eye and the external auditory meatus; used as a base line in positioning the skull. It is also called the Radiographic Base Line. d. An imaginary line running from the acanthion to the external auditory meatus and used as a base line in skull radiography. e. An imaginary line that traverses the skull from side to side passing through the pupils of the eyes; it is used as a base line for skull radiography.

148. Sternum and the acromion of the scapula **149.** The ulna and the radius **150.** The tibia and the fibula **151.** Temporal **152.** Superior **153.** Cecum **154.** Above the root of the nose and between the supraorbital borders, on the frontal bone **155.** The lower pointed segment of the sternum **156.** The joints of the wrist and the foot **157.** Right upper quadrant, left upper quadrant, right lower quadrant, left lower quadrant **158.** Inside the posterior abdominal wall, in the upper abdomen, behind the peritoneum, between the twelfth dorsal and third lumbar vertebrae **159.** The elbow **160.** e, f, b, a, c, h **161.** a. Of the head; b. Having origin outside the structure or organ involved; c. Motion towards or across the midline; d. Motion away from the midline **162.** Against; under; inside; under; above; middle or midline; away from the midline; to the front; to the back

163. Circulatory, digestive, endocrine, muscular, nervous, reproductive, respiratory, skeletal, urinary **164.** Articulation—the joint surface of a bone. Lumen—the channel of a tubular structure. Shaft—the body or major portion. Sinus—a natural cavity in the bone. Symphysis—the union of two paired bones. **165.** Skeletal **166.** The upper extremity—the hand **167.** Talus—one of the bones of the foot; it helps to form the ankle joint. Calcaneus—the heel bone of the foot. Tibia—one of the bones of the lower leg, lying medially to the fibula. Navicular—can be one of the bones of the wrist or one of the bones comprised in the foot. Scapula—the shoulder blade. Patella—the large sesamoid bone lying in front of the knee joint.

168. Between the bodies of adjacent vertebrae **169.** In the upper border of the sternum between the two depressions where the clavicles articulate **170.** Immediately below the orbit; it forms the prominent part of the upper cheek on each side **171.** The part of the temporal bone which extends down behind the ear and contains air cells **172.** The partition which divides the two halves of the chest cavity **173.** The ear or hearing **174.** Four: left atrium, left ventricle, right atrium, and right ventricle **175.** It is part of the collecting system that carries blood back to the heart **176.** Bile **177.** Operative cholangiography and I.V. cholangiography **178.** The medulla (hindbrain), which is the beginning of the spinal cord **179.** 90 degrees; upward **180.** Oblique **181.** Olecranon **182.** 30° **183.** Supine **184.** Shoulder **185.** Shallow-breathing

186. For the best result, the knees should be flexed and the feet should be flat on the table. This straightens the spine and brings it in closer contact with the film **187.** Sitting or standing; fifth lumbar vertebra **188.** 15°; head **189.** 10°; feet **190.** Sella turcica of the sphenoid bone **191.** A.P. lumbar, lateral lumbar, and oblique lumbar views **192.** The affected vertebra, usually the fifth lumbar **193.** Skull; slow inspiration **194.** Lateral; abdomen **195.** Emphysema – easy; arthritis – easy; hydrocephalus – easy; osteoporosis – easy; atrophy – easy

196. Make an exposure at your hospital using the same factors as are listed for Hospital A, and also make an exposure using twice the Ma.S. and half the Ma.S., all other factors remaining the same. From these resulting films, choose the best; if none of these are adequate, make the proper adjustment by halving or doubling again, until the desired exposure is obtained. This will be your adapted technique **197.** Contrast **198.** Minimum; maximum **199.** A cardboard holder; regular **200.** Radiographic contrast

201. Using the 15 per cent rule, you add 9 Kv.P. **202.** Kilovoltage **203.** Milliampere-seconds **204.** Kilovoltage **205.** Milliampere-seconds **206.** Milliampere-seconds or kilovoltage **207.** A small focal spot, close object-film distance, and increased focus-film distance **208.** Reduce secondary radiation **209.** Height; space **210.** Parallel; focused **211.** a. contrast; b. penetration; c. radiation fog; d. contrast; e. latitude; f. density **212.** a. magnification; definition; b. density **213.** a. quantity; b. density **214.** –

215. EMF – electromotive force; the electrical pressure of a charge. Potential – in physics, the available pressure of electricity. HVL – half-value layer: the thickness of a given substance which will reduce the intensity of the x-ray beam to one-half its original value. FFD – focus-film distance: the distance from the target of the x-ray tube to the film. Ohm – the unit of electrical resistance. Ampere – the unit of measurement of quantity of an electric current. Volt – the unit of electrical pressure or electrical potential. Kilovolt – 1000 volts

216. Watts **217.** Negative; positive **218.** Protons, neutrons, and electrons **219.** A source of electrons, target for the electrons to strike, and an electrical force to drive the electrons to the target **220.** Alternating current **221.** The amperage applied **222.** It preserves the life of the anode and allows greater heat capacity **223.** Less than 1 per cent **224.** Hard rays are the shorter, more penetrating rays attained at higher Kv.P.; soft rays are the longer, less penetrating rays attained at lower Kv.P.

STUDY QUESTIONS

Radiographic film, screens, cassettes

Check the statement below which is CORRECT:

Poor screen contact results in:

- ☒ Blurring of the radiographic image
- ☐ Increased object-film distance
- ☐ Black streaks at the edge of the film
- ☐ Magnification of the image

Check the statement below which is CORRECT:

The term "screen lag" refers to:

- ☒ The phosphorescence of the screen after the x-ray exposure stops
- ☐ The distance of the tube from the screens
- ☐ A damaged intensifying screen
- ☐ An intensifying screen in which the fluorescent crystals no longer fluoresce
- ☐ Poor contact between screens

Check the statement below which is CORRECT:

The speed of intensifying screens depends primarily on:

- ☒ The size of the fluorescent crystals
- ☐ The size of the focal spot used
- ☐ The type of film used
- ☐ Good screen contact
- ☐ Materials used in constructing the cassette

Check the statement below which is CORRECT:

Poor screen contact will result in:

- ☐ Increased sharpness of detail in the radiograph
- ☐ Increased contrast in the radiograph
- ☒ Decreased sharpness of detail in the radiograph
- ☐ Increased density in the radiograph
- ☐ Screen lag

Check the statement below which is CORRECT:

The back of a cassette is made of material opaque to x-rays because:

- ☐ It tends to protect the technologist from scattered radiation
- ☐ It tends to reduce distortion in the radiograph
- ☒ It tends to prevent fogging of the film by scattered radiation from behind the cassette

- ☐ It further intensifies the image
- ☐ It tends to reduce the amount of exposure necessary

Check the statement below which is CORRECT:

The essential chemical in an intensifying screen is:

- ☐ Silver iodide
- ☐ Silver bromide
- ☐ Calcium carbonate
- ☒ Calcium tungstate

Check the statements below which are CORRECT:

Intensifying screens:

- ☐ Have less speed when the tungstate crystals are large
- ☒ Permit a shorter exposure time than without screens
- ☒ Have less speed when the tungstate crystals are small
- ☐ Give more detail than without screens

Q. What is an intensifying screen?

A. An intensifying screen is a cardboard backing coated with a layer of chemical material which will fluoresce when penetrated by x-radiation. The chemical, a white crystalline salt called calcium tungstate, has the ability to emit a blue-violet light instantaneously upon the absorption of x-rays. The light emitted exposes the x-ray film, which is sandwiched between two intensifying screens.

Q. What is meant by lag in an intensifying screen?

A. Lag is a condition of the screen when it continues to emit light after the x-ray source has ceased.

Q. How many intensifying screens are usually used in each cassette?

A. Each cassette employs a front and a rear intensifying screen.

Q. Will dirt on the surface of the intensifying screen affect the radiograph?

A. Dust, dirt particles, and stains must not be allowed to collect on the surfaces of the screens because such foreign matter will cause extraneous shadows in the radiographic image.

Q. How would you determine if a spotted roentgenogram is due to a defect in an intensifying screen, to a defect in the cassette, or to the film itself?

A. A defect in an intensifying screen would produce a light spot. A defect in a cassette is apt to produce a defined shadow. The absence of the spot in a duplicate exposure on a second film would point to the film.

Q. What is meant by good screen contact? How do you test for it? What is its importance? What causes poor screen contact? How is it corrected?

A. Screens should be in contact with the film over its entire surface to maintain detail sharpness. Contact is tested by making a radiograph of $\frac{1}{4}$-inch wire mesh. If there are any areas in which contact is not maintained, an obvious loss of image sharpness is apparent in those areas. Correcting loss of contact necessitates removing the screen and building up underneath the area with sheets of paper in progressive sizes to obtain a flat screen surface.

This procedure is difficult and, unless extreme care is taken, may result in poor contact in areas not previously affected. It is recommended that the cassette be returned to the manufacturer for correction.

Q. Describe a cardboard film holder. Explain its construction. What is the importance of keeping the proper side up?

A. A cardboard film holder is a lightproof container used to envelop the x-ray film during the exposure. It is composed of two pieces of x-ray transparent paperboard hinged together with binding cloth. One of the cardboard covers contains a thin layer of lead foil which serves to absorb secondary radiation arising from the table top. Hence, this cover should be positioned away from the x-ray tube. The proper side of the cardboard holder which should face the tube is usually identified.

Q. Approximately how long will a pair of intensifying screens last?

A. Indefinitely. It is directly proportional to the amount of care they receive in handling and cleaning.

Q. What causes intensifying screens to deteriorate?

A. Improper handling and inadequate cleaning will reduce the life of the screen.

Check all CORRECT statements below:

Intensifying screen speed increases as:

☒ Temperature decreases
☒ Crystal size increases
☒ Crystal layer thickness increases
☒ KVP increases

Check the statement below which is CORRECT:

The phosphor which emits the yellow-green luminescence of the fluoroscopic screen is:

☐ Barium lead sulfate
☒ Zinc cadmium sulfide
☐ Zinc sulfide
☐ Calcium tungstate

Q. How does the speed of regular film compare to the speed of non-screen film?

A. Regular film is from 4 to 8 times faster.

Q. How do the speeds of fast screens and medium screens compare according to the adjustment that must be made in exposure.

A. Fast screens require a 50% reduction in Ma.S. over medium-speed screens.

Check the CORRECT statement below:

To reduce exposure of x-ray to the patient, the best screen to use is:

☐ Non-screen film
☐ Par-speed screen with regular film
☒ High-speed screen with high-speed film
☐ Slow-speed screen with high-speed film

Check the CORRECT statement below:

A property of gelatin in cool solutions is:

☐ It dissolves readily
☐ It precipitates
☐ It liquefies
☒ It swells

Check the statement below which is CORRECT:

Gelatin is chemically considered to be:

☐ A compound
☐ A mixture
☒ A colloid
☐ An element

Processing and darkroom technique

Q. What is a safelight and why is it used? How would you test a safelight for safety?

A. A "safelight" is a source of illumination, of a color and intensity that will not fog an x-ray film within a reasonable exposure time.

The "safelight" can be tested by placing an exposed but not developed film in a position similar to that in which films would be under ordinary working conditions. Then, using strips of cardboard, or other opaque material, about one inch wide, beginning at one end of the film place a strip of cardboard on the film at the end of each one-half minute of exposure. After a test of several minutes has been completed, develop the film. The elapsed time up to any fogged area may be measured by measuring the distance from this clear end of the film.

Q. What is meant by developer? What is it composed of?

A. Developer is the agent that reduces the exposed silver salts of the film emulsion to metallic silver so that when properly fixed it is visible to the human eye. Developer is generally composed of the developing agents hydroquinone and metol, the preservative sodium sulfite and the chemical sodium carbonate, which swells the gelatin in which the silver salts are suspended, so that the reducing agents may reach and act on the exposed silver salts in a minimum time.

Q. What is meant by the term "oxidized developer"? How can oxidation be prevented? What is the effect of oxidized developer?

A. Oxidized developer is developer that has become exhausted due to exposure to light and air. Oxidation can be reduced by placing a cover over the developer when it is not in use. Oxidized developer will generally stain films due to its discoloration.

Q. What is chemical fog?

A. Chemical fog is a gray, dull appearance of the films, generally caused by the use of too strong a chemical solution or aged developer.

Q. Can an underpenetrated film be corrected by prolonging the development and vice versa?

A. Only within relatively narrow limits, since overdeveloping cannot bring out anything which underexposure failed to put on the film.

Q. What is the proper height of solution level in tanks? How should it be maintained?

A. The proper level of solutions is such that the film, regardless of size, is fully immersed. Level should be maintained by adding either fresh solution or one of the special replenishing solutions.

Q. What determines the length of time for developing x-ray films and under what conditions should it be varied?

A. The time of development is determined by the temperature and age of the developer. As the solution ages or wears, developing time must be increased.

Q. How long and in what manner should a film be rinsed before putting it into the fixer solution?

A. A film should be rinsed for about 30 seconds in water or a "stop bath" before it is placed in the fixer solution. "Stop baths" are intended to stop the developing process and to remove excess developer so that it will not be carried to the fixer.

Q. How often should the developer and fixer be changed?

A. The developer should be changed when it shows signs of oxidation (brownish color) or when it will no longer bring up the blacks on the film. The fixer should be changed when it no longer hardens the emulsion or when the solution requires more than four times as long to fix a film as when the fixer was new, temperatures being the same.

Q. What is the normal appearance of developer and fixing solutions? What would lead you to suspect that something had gone wrong with them?

A. The normal appearance of the solutions is clear. Should either appear otherwise one should suspect that something has gone wrong.

Q. What is x-ray fog and how can it be prevented?

A. X-ray fog is a hazy or cloudy appearance on the radiograph due to the inadvertent exposure of the x-ray film to primary or secondary x-radiation. It can be prevented by storing films in lead-lined containers.

Q. How can the film be tested for x-ray fog?

A. By developing a film without exposing it first.

Q. How can light fog be prevented?

A. Light fog can be prevented by sealing all cracks in darkroom openings and using tested safelights.

Q. What are the usual causes, mode of differentiation, and means of prevention for fogging of films? staining of films?

A. Films are usually fogged by improper safelights, non-lightproof darkrooms, and x-rays. Safelight and light fogs manifest themselves as sharp, dark shadows, while x-ray fog can be recognized as a general all-over graying of the film, sometimes showing objects such as nails that are in the wall. Fogging can be prevented by the use of proper safelights, elimination of all white light in the darkroom, and storage of the film in suitable containers.

Staining of films is caused by old developing or fixing solutions. It can be prevented by establishing routines calling for the changing of the solutions before they have deteriorated to the point where they will stain films.

Q. What sometimes causes streakiness in the light areas of a developed film and how may this be avoided?

A. Streaks on films are generally caused by one of two things. Dirty hangers will cause streaks below the clips, or light areas on the film may have streaks under them if the film was not agitated.

Q. What is reversal action?

A. In reversal action, the normally dark areas are light on a film, and the normally light areas are dark. It is caused by extreme overexposure.

Q. If the following marks are found on an x-ray film, what are they due to and how would you prevent them: crinkle mark? friction mark? pinhole mark? water spot? static mark? clear circles?

A. A crinkle mark is caused by kinking the film. It should be kept flat. Friction marks are a series of static discharges on the film caused by sliding the film across the wrapping paper or other surface. A pinhole mark is a single static discharge point—generally caused by uneven drying, usually in a dryer that is too hot.

Water spots may be due to improper film drying or to water wetting the film in one area and then drying before film development.

A static mark is any indication on the film of static discharge, generally caused by friction.

Clear circles on the films are caused by air bubbles clinging to the film surface during development. The film should be agitated to remove them.

Q. What precautions must be taken with respect to developing, washing, and fixing "non-screen" films?

A. Non-screen film because of the heavier emulsion should be developed, rinsed, fixed, and washed about 30 per cent longer than the regular film.

Q. What is a penetrometer? How is it used?

A. A penetrometer is a radiographic test device usually made of aluminum and built up in steps of varying thickness. It is used in testing the radiographic efficiency of x-ray equipment and for radiographic calibrations, since minor changes in radiographic density can readily be detected and the proper compensation or adjustment can be made.

Q. If a given exposure causes a certain density when processed 5 minutes at 68 degrees, what developing time must be used to produce the same density when developer temperature is:

1. 64 degrees?
2. 74 degrees?

3. 80 degrees?
4. 70 degrees?

A. A good rule to follow: If the temperature of the developer is higher than the recommended 68 degrees, subtract approximately 1/4 minute per degree of the increase in temperature; if the temperature of the developer is lower than the recommended 68 degrees, add approximately 1/4 minute per degree of decrease in temperature. Therefore the answers to the above variations in temperature would be:

1. 6–6 1/4 min.
2. 3 1/2–3 3/4 min.
3. 2–2 1/4 min.
4. 4 1/2 min.

Check the statement below which is CORRECT:

The darkroom safelight should have a 10-watt white light bulb behind a:

☐ 2 mm. aluminum filter
☒ Wratten 6-B filter
☐ Red acetate filter
☐ Wratten 10-A filter

Check the statement below which is CORRECT:

Chemical fog is produced by:

☐ Cold developer
☐ Incomplete development
☐ Hot hypo
☒ Prolonged development

Check the statement below which is CORRECT:

If the air in the darkroom is too dry, film is susceptible to:

☐ Crescent-shaped markings
☐ Fingerprints
☐ Chemical fog
☒ Static accumulation

Check the statement below which is CORRECT:

The emulsion used in making x-ray film contains:

☐ Silver nitrate
☐ Sodium sulfite
☒ Silver bromide
☐ Calcium tungstate

Check the statement below which is CORRECT:

Reticulation on the surface of an x-ray film is the result of:

☐ Developer carried into the hypo
☒ Sudden changes in the temperatures of the solutions
☐ Incorrect mixing of the developer
☐ Drying in too warm air

Check the statement below which is CORRECT:

The chemical in the developer which reduces oxidation is:

☒ Sodium sulfite
☐ Sodium carbonate

☐ Potassium bromide
☐ Sodium sulfate

Check the statement below which is CORRECT:

The color of chemical fog on an x-ray appears to be:

☒ Gray
☐ Black
☐ Brown
☐ Yellow

Check the statement below which is CORRECT:

The latent image is the result of:

☐ Action of hydroquinone
☐ Films stored in too great heat
☒ Exposure to x-ray
☐ Fixing and washing the film

Check the statement below which is CORRECT:

The compound that is used in intensifying screens as a fluorescent agent is:

☐ Silver bromide
☒ Calcium tungstate
☐ Calcium carbonate
☐ Potassium bromide

Check the statement below which is CORRECT:

"Christmas tree-like" density defects on an x-ray film are caused by:

☐ Movement of patient
☐ Dust
☒ Static
☐ Overexposure

Check the statement below which is CORRECT:

Moon-shaped areas of decreased density on x-ray film are caused by:

☐ Static
☐ Excessive heat
☒ Bending of film
☐ X-radiation leaking in storage room

Match:

6	Potassium bromide	1. Preservative
7	Sodium thiosulfate	2. Hardening agent
1	Sodium sulfite	3. Activator
5	Acetic acid	4. Developing agent
4	Hydroquinone	5. Acidifier
3	Sodium carbonate	6. Restrainer
2	Potassium alum	7. Fixing agent
4	Elon	

Study Questions

True-false: With 5-minute development, the film speed is about 35 per cent more than is obtained with 3-minute development. T .

True-false: The effect of agitation is equivalent to approximately a 60 per cent increase in development. F .

Equipment and accessories

Check the statement below which is CORRECT:

Magnification distortion can be lessened by the use of:

☐ Cones
☐ A Bucky diaphragm
☒ A longer target-film distance
☐ The use of filters
☐ A shorter target-film distance

Check the statement below which is CORRECT:

If an ordinary 8-to-1 Potter-Bucky diaphragm is used, how much greater is the exposure than if the Bucky is not used?

☐ It is the same
☒ 3 times greater
☐ 8 times greater
☐ 10 times greater
☐ 12 times greater

Check the statement below which is CORRECT:

The grid-ratio of a Potter-Bucky diaphragm is:

☒ The ratio of the height of the lead strips to space between strips
☐ The ratio between the total thickness of the grid and the space between lead strips
☐ The ratio between the speed of travel of the grid and the speed of the timer
☐ The ratio of exposure time without the Bucky to exposure time with the Bucky
☐ The ratio of the width of the lead strip to the depth of the strip

Check the statement below which is CORRECT:

The Potter-Bucky diaphragm and the Lysholm or stationary grid are used to:

☐ Localize foreign bodies in the eye
☒ Eliminate a large portion of secondary radiation
☐ Limit the diameter of the primary beam
☐ Produce radiographs free from distortion
☐ Record movements of various organs of the body

Check the statement below which is CORRECT:

The apparatus used for laminagraphy, planigraphy, or tomography is used for:

☐ Developing films rapidly
☐ Producing bedside radiographs
☐ Examining the bladder with light and lens

☒ Producing body-section radiographs
☐ Recording movements of the heart

Check the statement below which is CORRECT:

Cones and cylinders are used in radiography to:

☐ Permit the use of less kilovoltage
☒ Limit the field of radiation and reduce secondary radiation
☐ Reduce wear and tear on the x-ray tube
☐ Focus the x-ray beam
☐ Shorten the exposure

Check the statement below which is CORRECT:

A Bucky diaphragm should not be used in making radiographs of:

☐ The lateral lumbar spine
☒ The lateral cervical spine
☐ The lateral sacral spine
☐ The anteroposterior dorsal spine
☐ The anteroposterior lumbar spine

Check the statement below which is CORRECT:

Cones, stationary grids, and Bucky diaphragms are similar in that their primary function is to:

☐ Protect the technologist from scattered radiation
☐ Reduce distortion in the radiograph
☒ Reduce secondary radiation
☐ Reduce exposure time
☐ Permit using a longer target-film distance

Check the statement below which is CORRECT:

Magnification in a radiograph can be lessened by the use of:

☐ Cones
☒ Longer target-film distance
☐ Filtration
☐ Shorter target-film distance
☐ The Bucky diaphragm

Check the statement below which is CORRECT:

All other factors being the same, which of the following exposure would produce the greatest radiographic density?

☐ $^{1}/_{10}$ second and 100 Ma.
☐ 1 second and 10 Ma.
☐ $^{1}/_{20}$ second and 200 Ma.
☒ $^{1}/_{40}$ second and 500 Ma.
☐ $^{1}/_{15}$ second and 150 Ma.

Check the statement below which is CORRECT:

Contrast in a radiograph is increased by:

☐ Greater film distance
☐ Increased kilovoltage
☒ Decreased kilovoltage
☐ Use of non-screen film
☐ Full-wave rectification

Check the statement below which is CORRECT:

Detail in a radiograph is not improved by:

- ☐ The use of cones and cylinders
- ☒ Increased object-film distance
- ☐ Increased focus-film distance
- ☐ Immobilization
- ☐ The use of non-screen film

Q. What is a wafer grid? For what purpose is it used? What is the difference between the wafer grid and the Bucky diaphragm?

A. A wafer grid is a thin laminated structure, made up of alternate strips of x-ray opaque and x-ray transparent materials, used over the film or cassette for the reduction of secondary radiation. The x-ray opaque material is lead, and the transparent material may be thin wood, treated paper, or one of the lighter elements such as tin or zinc. The wafer grid is a finer grid and is stationary when in use whereas the Bucky diaphragm is moved during exposure.

Q. What causes grid lines on a radiograph and how may they be corrected?

A. Lines may be caused by improper centering of the tube, by increasing or decreasing the distance from the proper distance at which the grid is focused, by an improper relationship between the exposure time and the grid travel time, or by beginning the exposure before the grid starts in motion or continuing the exposure after it stops.

Q. Of what use is a cone in radiography and where is it used?

A. A cone restricts the x-ray beam to the immediate area under examination and thus minimizes secondary radiation by limiting the volume of tissue exposed. The result is greatly increased contrast, which makes radiographic detail more plainly visible. For regions such as sinuses, gallbladder, with or without Potter-Bucky diaphragm, a cone should be used to cover the desired area—particularly for heavy parts without the Potter-Bucky diaphragm.

Q. Must the shift of the tube in stereoscopy be accompanied by a tube tilt? Explain your answer.

A. In stereoscopy the shift of the tube must be accompanied by a tube tilt if a small cone is used. Unless this is done, the shifting of the cone circle may result in cut-off of the portion of the part being radiographed. If no cone is used, or if a very long focal-film distance, such as is used in chest work, is employed, the tilt is not necessary. In stereoscopy work on the head, however, where a four-inch cone or one even smaller may be used at 30- or 36-inch focal-film distance, it is necessary to tilt the tube and direct it to the same centering point for both views.

Physics, electricity

Q. What is matter?

A. Anything which occupies space. Examples: steam, ice, water.

Q. What is an atom?

A. The smallest part of a molecule. It is made up of electrons, protons, and neutrons.

Q. Define *electron.*

A. The electron is the smallest measurable quantity of negative electricity.

Q. Define *proton.*

A. The proton is the smallest measurable quantity of positive electricity.

Q. Define *neutron.*

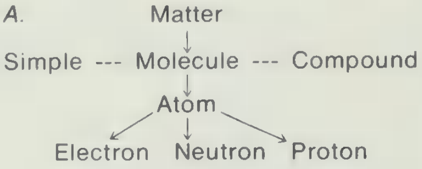
A. The neutron is an electrically neutral part of an atom.

Q. Define *molecule.*

A. The molecule is the smallest part of matter that can exist by itself and still show the characteristic properties of the original substance.

Q. Diagram the structure of matter.

A.



Q. When pressure has established a state of imbalance in an atom, how does the atom achieve a return to stability?

A. The atom has a natural tendency to return to a neutral state and it will immediately attract electrons from other sources to restore its neutrality.

Q. When an electron is removed from an atom, how is the atom charged?

A. Positively.

Q. When a free electron attaches to an atom, how does the atom become charged?

A. Negatively.

Q. What is electricity?

A. The flow of negatively charged particles, called electrons, along wire conductors.

Q. Define *ohm.*

A. An ohm is a unit of electrical resistance.

Q. Define *volt.*

A. A volt is a unit of electrical pressure. One volt is the amount of electrical pressure required to force one ampere of electrical current through one ohm of electrical resistance.

Q. Define *ampere.*

A. An ampere is a unit of electrical current. One ampere is the amount of electrical current forced through one ohm of resistance by the electrical pressure of one volt.

Q. Distinguish between a good conductor and a good insulator. Name one of each.

A. A good conductor is any material which permits a free flow of electrons, such as copper wire. A good insulator is any material that impedes the flow of electrons, such as glass.

Q. Define *milliampere.*

A. A milliampere is $^1/_{1000}$ of an ampere.

Q. Define *kilovolt.*

A. A kilovolt is equal to 1000 volts.

Q. Define *peak kilovolt.*

A. Peak kilovolt is the highest kilovoltage at any time in an electrical cycle.

Q. What is an ammeter?

A. A device used to measure amperes.

Q. What is a voltmeter?

A. A device used to measure volts.

Q. What is a galvanometer?

A. An instrument used to measure small amounts of current.

Q. What is a resistor?

A. A device which offers a great resistance to the flow of electrons. Some resistors offer resistance in varying degrees and can be manually controlled.

Q. What is an ohm?

A. The unit of resistance. An electromotive force of 1 volt will move an electric current of 1 ampere against the resistance of 1 ohm.

Q. What is a magnet?

A. A bar or horseshoe-shaped piece of iron which has the power to attract pieces of iron to its poles. This is called magnetism. A compass needle is said to be a bar magnet. The pole of the needle pointing to the north has a north-seeking or north pole. The earth is a big magnet with magnetic poles near its north and south geographical poles. In the space around the magnet there is a field of force.

Q. Do electric currents show magnetic effects?

A. Yes. A compass needle held close to a straight wire with direct current passing through it will turn its needle perpendicular to the wire and the current. This shows the presence of a magnetic field around the wire. There is no movement of electrons without this field of energy and this movement continues until the magnetic field disappears. It may be that each moving electron creates its own field of energy.

Q. What is electromagnetic induction?

A. This is the production of an electric current in a wire coil by placing it within a magnetic field which surrounds another wire coil. The current is produced even though there is no electrical connection between the coils.

Q. What is a magnetic field?

A. An area of magnetic force which surrounds an electric charge of current.

Q. Does a magnetic field exist at right angles to or parallel to an electric conductor?

A. At right angles.

Q. Distinguish between static and current electricity.

A. In static electricity the electric charge is at rest. In current electricity, the charged particles flow along a conductor.

Q. What is mutual inductance?

A. This is the establishment of a voltage in a wire coil either by moving a conductor across magnetic lines of force or by having the magnetic field change polarity, causing the magnetic lines to cut across a conductor.

Q. What is a transformer?

A. A device used to transfer electrical energy from one circuit to another and either raise or lower the voltage without the two circuits being electrically connected to one another.

Example: If the windings of wire in the primary circuit are 100 and those of the secondary circuit 100,000, the voltage in the secondary circuit will be 1000 times as great as that in the primary circuit.

Q What is the structure of a step-up transformer?

A The number of turns of wire is greater in the secondary coil than in the primary coil. This causes an increase in voltage.

Q What is the structure of a step-down transformer?

A. The number of turns of copper wire in the primary coil is greater than those in the secondary coil. This results in a decrease in voltage.

Q What is an autotransformer?

A. A device used to select the amount of voltage to introduce into the primary coil of the step-up transformer. It consists of a single winding of copper wire around an iron core. Leads are taken off from various turns of the coil, allowing a selection of the amount of voltage to let in. It is generally used as a step-down transformer.

Q. What is meant by the ratio of a transformer?

A. The ratio of a transformer is the relation of the number of turns on the primary to the number of turns on the secondary.

Q. What is meant by frequency of an alternating current? What frequencies are commonly used?

A. The frequency of an alternating current is the number of times the current changes from positive to negative to positive per second. The common frequencies are 25 cycles, 50 cycles, and 60 cycles.

Q. What are the properties of x-rays?

A. 1. The ability to penetrate solids and opaque media.
2. The ability to darken photographic film.
3. The ability to emit light (fluorescence) when they strike certain substances.

Q. Name the three necessary conditions for the production of x-rays.

A. 1. A concentration of electrons.
2. The movement of those electrons at a high speed.
3. Sudden stoppage of electrons by striking a target.

Q. How are x-rays produced?

A. The electrons, which are negatively charged particles traveling at a high speed through a metal conductor, are forced to cross a gap in the conductor and strike a metal target on the other side of the gap. The target is positively charged and thus attracts the negatively charged electrons. At the target the electrical energy is converted into light energy and we then have x-rays.

Q. What is the usual electric voltage used?

A. 110 or 220 volts.

Q. How may 110 or 220 volts be increased to say 50,000 volts?

A. By the use of a step-up transformer.

Q. How may 110 or 220 volts be decreased to say 5 volts?

A. By the use of a step-down transformer. This is used to heat the filament of the x-ray tube.

Q. Which is more penetrating, an x-ray with a short wave length or one with a long wave length?

A. The short wave length is more penetrating.

Q. What is the unit of measurement of wave lengths?

A. The angstrom unit (Å). One angstrom unit is equal to .00000001 centimeter ($^1/_{100,000,000}$ centimeter, or one one-hundred-millionth of a centimeter).

Q. What is the electromagnetic spectrum?

A. The grouping of electromagnetic waves or radiations according to their wave length.

Q. What are some of the rays of the electromagnetic spectrum?

A. Electric, microwaves, infrared, ultraviolet, television, radio, visible light, x-rays, gamma rays, cosmic rays.

Q. Upon what does the penetrability of x-rays produced depend?

A. The penetrability of x-rays depends on the kilovoltage at which they are produced or, more specifically, on their wave length.

Q. What is meant by *hard rays?* By *soft rays?*

A. Hard rays are rays produced at relatively high kilovoltage and are more penetrating than the soft rays, which are produced at relatively low kilovoltage. Hard rays are short-wave-length rays and soft rays are long-wave-length rays.

Q. What is the fundamental relation between kilovolts impressed on an x-ray tube and the quality of the emergent beam?

A. The quality of hardness of an x-ray beam increases as the voltage increases, decreases as the voltage decreases. The wave length of the beam becomes shorter as the kilovoltage increases and longer as the kilovoltage decreases.

Q. What meters are necessary in an x-ray machine? For what purpose is each used, and where is each located in the circuit?

A. The necessary meters in an x-ray machine are an ammeter, milliammeter, and a voltmeter. The ammeter measures the filament current and is in the primary circuit to the filament transformer. The Ma. meter measures the current flowing through the x-ray tube and is in the high-tension circuit. The voltmeter is in the primary circuit of the high-tension transformer and indicates the voltage applied to the primary of the high-tension transformer.

Q. How is electricity flowing through a conductor like water running through a pipe?

A. Water flowing through a pipe flows in one direction at a constant volume similar to direct current through a wire. It encounters resistance to its flow and therefore must have pressure behind it to cause the water to flow. In an electrical system the equivalent pressure is voltage and the resistance ohms. Flow of electricity may be likened to the flow of water in a pipe; the voltage corresponds to pressure—the higher the voltage, the more current or water flow. The current or amperage corresponds to gallons per minute. Resistance in the electrical flow corresponds to friction or resistance to the water flow—the larger the wire or water pipe, the more current or water flow with the same voltage or water pressure.

Q. Can a direct current be used to operate a transformer? If only direct current is available, how could you work an x-ray machine?

A. A direct current cannot be used to operate a transformer. If only direct current is available it must be converted to alternating current by a device called a rotary converter.

Q. Describe how an x-ray tube functions.

A. The filament is electrically heated to the point where free electrons are liberated. High potential is placed across the tube focusing the electrons, accelerating the electrons to high velocity, and causing them to bombard a predetermined area on the target.

Q. What do you understand by the term "hot-cathode" tube?

A. The term describes the type of x-ray tube invented by Dr. Coolidge in which the operation depends upon the heated filament as an electron source.

Q. Is the filament control in the low- or the high-voltage portion of the circuit?

A. In the low-voltage portion.

Q. What is self-rectification?

A. When high voltage is applied to an x-ray tube only those alternations above the base line are of value, and cause electrons to be cast off to the target of the tube. During the period of alternations below the base line no electrons are given off and thus no x-rays are produced. This is due to the fact that the anode of the tube (containing the target) is positive and negative alternatingly with relation to the cathode during each half cycle. When the anode is positive, the negative electrons at the cathode are attracted to the anode and x-rays are produced. When the anode is negative, electrons are not attracted. Self-rectification is used in portable and dental x-ray machines for light x-ray work.

Q. What is half-wave rectification?

A. If heavier work is demanded from an x-ray tube, it cannot act as a self-rectifier. A valve tube must be used in the circuit of high voltage which prevents the unused voltage (alternations below the base line) from being applied to the x-ray tube. This tube has a large cathode filament which produces an abundance of electrons which are bombarded against the entire face of the anode (target).

Q. What is valve-tube rectification (full-wave)?

A. This is the use of four valve tubes in the circuit so that the alternations above the base line fill in the gap ordinarily utilized by the alternations below the base line. The first two valve tubes carry electrons from the alternations above the base line to the x-ray tube. The next two valve tubes then complete the circuit. This gives maximum use of voltage and equipment.

Q. Why is alternating current better than direct current?

A. It can be sent over long distances with a minimum of loss in transit. It is also possible to cut it down from high voltage to the 110 or 220 voltage needed in homes and offices.

X-rays and tubes

Q. Explain the theory of the double-focus tube.

A. The double focus is designed to offer a small projected focal spot where low Ma. values can be used for a period of time long enough to obtain the quantity of radiation required. The large focal spot is used where involuntary motion is encountered in the subject requiring short exposure time. To obtain the required amount of exposure, higher Ma. values are necessary. As a limited amount of energy (Ma.) can be focused over a given area on the target for a certain period of time before the target will be damaged, double-focus tubes are necessary where the sharpest detail is desired.

Q. Explain the theory of operation and advantages of a "rotating-target" tube.

A. The amount of energy which can be focused over a given area on the target of the tube is limited by the size of the area and the melting point of the target material. The "rotating-target tube" has a beveled tungsten disk on the anode stem which is caused to rotate at a nonsynchronous speed. By this means relatively cool tungsten is brought under the electron stream, thus avoiding some of the limitations on the rating of the tube by the melting point of the target materials. With the "rotating-target" tube higher Ma. values are possible with smaller focal spots.

Q. From the standpoint of tube rating and factor of safety, which would be the more conservative method of increasing film density, increasing tube current (Ma.) or increasing Kv.P.?

A. From the standpoint of tube rating and factor of safety the more conservative method of increasing film density would call for increasing Kv.P. within the limits of the tube. Exposure time would be the second choice as a variable factor to increase density.

Q. What is meant by the term "gassy" tube, and to what condition or conditions is it attributed?

A. Usually a "gassy" tube is one which has had the vacuum affected by the liberation of gas molecules from the elements by excessive heating or where damage to the glass envelope has affected the vacuum. With a poor vacuum and gas molecules present, the high voltage will ionize the gas, permitting an unpredictable current to flow through the tube.

Q. What causes pitting of the target? Is this harmful to the tube?

A. Pitting of the target is usually due to overloading the focal area by the use of excessively high current values. If the pitting is severe the quantity of useful radiation will be diminished.

Q. Distinguish between actual and effective focal-spot size.

A. The effective focal spot is the projected focal-spot size of the tube as measured directly below the target area bombarded by electrons. The actual focal spot is the area bombarded by the electron stream and is approximately three times as long as it is wide.

Q. What are the advantages and disadvantages of a small focal spot?

A. The smaller focal spot produces radiographs with sharper detail. However, when the smaller focal spot is used, lower Ma. values must be employed.

Check the statement below which is CORRECT:

The energy level of electrons in the inner orbits of atoms is:

☒ High
☐ Low

Check the statement below which is CORRECT:

In a normal atom, the following number of negative charges should be present to counteract the number of positive charges in the nucleus:

☐ Twice as many
☒ The same number
☐ Half as many
☐ Four times as many

Study Questions

Check the statement below which is CORRECT:

Electricity is a form of energy primarily because it:

- ☐ Occupies space
- ☒ Can do work
- ☐ Has weight
- ☐ Has inertia

Check the statement below which is CORRECT:

The voltage in the filament circuit of an x-ray tube usually is approximately:

- ☐ 220–240 volts
- ☒ 10–15 volts
- ☐ 110–115 volts
- ☐ 30–150 Kv.P.

Check the statement below which is CORRECT:

The purpose of the choke coil (variable resistor) in an x-ray circuit is to regulate the current delivered to the:

- ☐ Primary windings of the x-ray transformer
- ☐ Autotransformer
- ☐ Filament transformer of rectifier tube
- ☒ Filament of x-ray tube

Check the statement below which is CORRECT:

The following does not significantly affect the strength of an electromagnet:

- ☒ Voltage
- ☐ Amperage
- ☐ Turns in the coil
- ☐ The core

Check the statement below which is CORRECT:

The amount of electrical current flowing in a conductor is measured in

- ☐ Ma.
- ☐ Kilovolts
- ☒ Amperes
- ☐ Volts

Check the statement below which is CORRECT:

The current flowing between the transformer and the rectifier is:

- ☐ Direct current
- ☐ High frequency current
- ☐ Pulsating direct current
- ☐ Unidirectional current
- ☒ Alternating current

Check the statement below which is CORRECT:

Electrical pressure is measured in:

- ☐ Amperes
- ☒ Volts

- ☐ Ohms
- ☐ Watts
- ☐ Ergs

Check the statement below which is CORRECT:

A good insulator is:

- ☐ Copper
- ☐ Silver
- ☐ Salt water
- ☒ Oil
- ☐ Aluminum

Check the statement below which is CORRECT:

Since the voltage in the secondary of a step-up transformer is higher than in the primary:

- ☐ Electrical potential in the secondary is higher than in the primary
- ☐ The frequency of alternations is increased
- ☒ Milliamperage in the secondary is less than in the primary
- ☐ The milliamperage is increased in the secondary
- ☐ The frequency of alternations is decreased

Check the statement below which is CORRECT:

The ratio of a transformer is determined by:

- ☐ The relation of the size of the wires in the primary winding to those in the secondary
- ☐ The relation of the voltage impressed on the primary to the voltage produced in the secondary
- ☒ The relation of the number of turns in the primary to the number of turns in the secondary
- ☐ The relation of the current produced in the secondary to the resistance in the primary

Check the statement below which is CORRECT:

A voltage compensator is used to:

- ☐ Protect the primary circuit from overload
- ☐ Supply a predetermined amperage to the transformer
- ☐ Prevent a short circuit
- ☒ Supply a predetermined voltage to the autotransformer

Check the statement below which is CORRECT:

Of wires of identical material, the one that offers the least resistance to the flow of an electric current is:

- ☒ Short and thick
- ☐ Long and thin
- ☐ Short and thin
- ☐ Long and thick

Check the statement below which is CORRECT:

The wave lengths of x-radiation generally used in radiography are:

- ☐ Longer than visible light
- ☒ Longer than gamma rays

- ☐ Shorter than radium radiation
- ☐ Longer than ultraviolet rays
- ☐ Longer than infrared rays

Check the statement below which is CORRECT:

Each wave or quantum of x-ray energy travels at the speed of:

- ☐ 1180 feet per second
- ☐ 500 miles per hour
- ☒ 186,000 miles per second
- ☐ 53.7 feet per second
- ☐ 88 feet per second

Check the statement below which is CORRECT:

The quality of the x-ray beam is dependent on:

- ☐ The size of the focal spot
- ☒ The voltage impressed on the tube
- ☐ The heat of the filament
- ☐ The type and size of target
- ☐ The milliamperage

Check the statement below which is CORRECT:

The quantity of electrons in the cathode stream is dependent directly on:

- ☐ The size of the focal spot
- ☐ The voltage impressed on the tube
- ☒ The heat of the filament
- ☐ The type and size of target
- ☐ The kind of filter used

Check the statement below which is CORRECT:

The following is not a property of x-rays:

- ☐ Photographic effect
- ☐ Fluorescent effect
- ☒ Recoil effect
- ☐ Ionizing effect

Check the statement below which is CORRECT:

The heel effect is a variation in x-ray intensity output:

- ☐ At the tube window
- ☐ Along the cathode of the tube
- ☒ Along the longitudinal axis of the tube
- ☐ Along the transverse tube axis

Check the statement below which is CORRECT:

The heel effect is limited in its application when using:

- ☐ Short focal-film distance
- ☐ Long focal-film distance
- ☐ Long object-film distance
- ☒ A large film at short focal-film distance

Q. What are the fundamental properties of x-rays and how may they be detected?

A. Among the properties of x-rays the following are the most important.

a. X-rays cause certain substances to fluoresce, thus producing visible light. Therefore, a fluoroscopic screen can be used to detect x-rays.

b. X-rays produce a change in photographic film similar to the action of light. A film subjected to radiation will show blackening when developed. An unexposed film could be used to detect the presence of x-rays.

c. X-rays increase the electrical conductivity of air through which they pass. This is called ionization and is used as a basis for measuring and detecting radiation.

d. X-rays produce certain biological changes in cells that may stimulate or retard growth. In some cases the cell may be destroyed or the form of new cells may be altered.

e. X-rays can be diffracted in much the same manner as light. This property makes x-rays a useful tool in the investigation of molecular structure of materials.

Q. How are x-rays produced?

A. A beam of rapidly moving electrons is caused to strike some form of matter. The bombardment of this "target" matter by the electrons results in the production of x-rays and heat.

Q. Can x-rays be controlled and how?

A. X-rays can be controlled by varying the voltage across the x-ray tube and by varying the current through the tube. The voltage across the tube determines the quality or penetrating power of the x-rays and also has considerable effect on the quantity. Variations of the current through the tube, which are dependent chiefly on the temperature of the filament, cause similar variations in quantity of x-rays produced but have very little effect on the quality.

Q. What portion of the total energy delivered to an x-ray tube at the target is given off as x-rays? What becomes of the remaining energy?

A. In most x-ray apparatus, less than 1 per cent of the total target energy is converted to x-rays. The remaining energy appears as heat and other forms of energy.

Q. If x-rays are invisible, how may their presence be detected?

A. The presence of the rays may be detected by their effects on photographic film and on fluorescent substances and by their ability to ionize the air through which they pass.

Q. If x-rays penetrate all materials, how then is it possible to apply them to radiography?

A. X-rays do not penetrate all matter to the same extent. The penetration of a given material will depend on its thickness and chemical composition. Because of the varying degrees of penetration for different materials, it is possible to differentiate between the various tissues in the body.

Q. What is primary radiation? secondary radiation?

A. Primary radiation is that radiation generated at the focal spot of the x-ray tube.

Secondary radiation is that radiation caused by the primary radiation striking some material. The quality of the secondary radiation is dependent on the atomic number of the material and is usually quite different from that of the primary radiation.

Q. Why is it necessary to have a filament in an x-ray tube? Explain fully.

A. The filament of the x-ray tube is the source of electrons. In order to produce x-rays, it is necessary to have a rapidly moving beam of electrons strike a target. The filament, when heated, emits electrons. These electrons are shaped into a beam by the cathode structure. The rapid motion of the electrons is caused by the potential difference between the anode and cathode.

Q. What is a line-focus tube?

A. A line-focus tube has a straight-line filament so arranged that the electron flow strikes the target, forming a narrow-strip focal spot. The angle at which the target tips is such that the projection of this strip on the film is a small rectangle called the effective focal spot.

Q. How do you determine the prime factors (Kv.P., time, Ma.) that may be safely employed with reference to a given tube and apparatus?

A. The prime factors that may be safely employed with a given tube and apparatus are determined from the equipment-rating charts supplied by the manufacturer.

Q. How would one check the timer of an x-ray machine for exposures of less than $^{2}/_{10}$ second?

A. To check the timer of an x-ray machine for exposures of less than $^{2}/_{10}$ second, a spinning top, consisting of a lead disc superimposed on a brass plate and revolving about a pivot point, is placed on a film beneath the x-ray tube. An exposure of $^{1}/_{10}$ or $^{2}/_{10}$ second is made, and the accuracy of the timer may be determined by counting the number of black dots which show on the processed film. At $^{1}/_{10}$ second, utilizing self or half-wave rectification, the dots should be six in number; for full-wave rectification, they should be twelve in number.

Q. When a spinning top is used for checking a timer, what effect does speed of rotation have?

A. Speed of rotation of a spinning top has no effect on results of checking a timer, providing the individual dots on the film can be distinguished.

Q. What is an impulse timer and what are its applications in radiography?

A. An impulse timer is a very accurate x-ray timer which times an x-ray exposure in exact multiples of one impulse; that is, it starts an exposure at a zero point of the alternating voltage supplied to the high voltage transformer and interrupts it at a zero point of some subsequent impulse. It permits the use of very accurately controlled high-energy exposures.

Check the statement below which is CORRECT:

The direction of electron flow through an x-ray tube is:

☐ From positive to negative terminal
☐ Determined by the heat of the filament
☐ From anode to cathode
☐ Determined by the shape of the focusing cup
☒ From negative to positive terminal

Check the statement below which is CORRECT:

In checking the timer of a full-wave rectified x-ray machine using a spinning top for $^{1}/_{10}$ of a second, the number of dots recorded should be:

☐ 6 ☒ 12 ☐ 18 ☐ 20 ☐ 60

Check the statement below which is CORRECT:

In half-wave rectified x-ray machines operating with a 60-cycle current the number of impulses per second passing through the x-ray tube is:

☐ 12 ☐ 6
☐ 18 ☒ 60
☐ 30 ☐ 120

Check the statement below which is CORRECT:

The rheostat changes the voltage by:

☐ Shorting the filament transformer
☒ Varying the amount of resistance
☐ Cutting out part of the transformer
☐ Cutting out all of the transformer
☐ Increasing the number of windings in the primary of the transformer

Check the statement below which is CORRECT:

The flow of electrons through a conductor is termed:

☐ Static electricity
☐ Reticulation
☐ Rectification
☐ Chemical action
☒ Current electricity

Check the statement below which is CORRECT:

The term 'amperage' is used to describe:

☐ The direction of flow of electrons through a conductor
☐ The resistance offered to the flow of electricity
☒ The number of electrons passing a given point in a conductor in a given period of time
☐ The electromotive force impressed upon the conductor
☐ The amount of ionization produced in a given quantity of air in a given period of time

Study Questions

Check the statement below which is CORRECT:

A line voltage compensator is located:

☒ In the primary circuit
☐ In the secondary circuit
☐ Just before the rectifier
☐ Just after the rectifier
☐ In the filament circuit

Check the statement below which is CORRECT:

The advantage of the rotating-anode x-ray tube over the stationary-anode tube is:

☐ Its low cost
☐ It permits lower energies to be used
☐ It is small and easily manipulated
☒ It permits high energies with a small focal spot
☐ The focal spot gets hotter

Check the statement below which is CORRECT:

If an x-ray tube is gassy the following will usually be noted:

☐ No reading can be obtained on the primary voltmeter
☐ The tube filament does not light up
☐ The milliammeter does not register any current
☒ There are irregular fluctuations in milliamperage
☐ The valve tubes will not light up

Check the statement below which is CORRECT:

Like poles of a magnet:

☒ Repel each other
☐ Attract each other
☐ Neutralize each other
☐ Do not affect each other
☐ Must be made of different materials

Check the statement below which is CORRECT:

Milliamperage across the x-ray tube for any given exposure is correlated with:

☐ The heat of the anode
☒ The heat of the filament
☐ The size of the target
☐ The distance between anode and cathode
☐ The voltage applied to the tube

Check the statement below which is CORRECT:

Ohm's Law is expressed by:

☒ Amperes equal $\frac{\text{Volts}}{\text{Ohms}}$

☐ Volts equal $\frac{\text{Watts}}{\text{Amperes}}$

☐ Horsepower is $\frac{\text{Watts}}{746}$

☐ Volts equal Amperes x Watts

☐ A equals ½ bh

Check the statement below which is CORRECT:

In comparison with the average wave length of the primary beam the wave length of the scattered radiation is:

☐ Shorter

☒ Longer

☐ Of greater intensity

☐ More irregular

☐ More penetrating

Check the statement below which is CORRECT:

In an x-ray tube the cathode stream consists of:

☐ High speed protons

☒ High speed electrons

☐ High speed neutrons

☐ High speed photons

☐ High speed alpha particles

Check the statement below which is CORRECT:

The source of electrons in a rotating-anode tube is:

☐ The rotor

☐ The target

☒ The filament

☐ The anode

☐ Gas particles in the tube

Check the statement below which is CORRECT:

In general, comparing deep therapy x-ray tubes with those used in radiography, the therapy tube uses:

☐ Higher Ma. and lower Kv.P.

☒ Lower Ma. and higher Kv.P.

☐ Lower Ma. and lower Kv.P.

☐ Higher Ma. and higher Kv.P.

☐ About the same Ma. and Kv.P.

Check the statement below which is CORRECT:

The voltage lost in overcoming the resistance in the conductor of a line is known as:

☐ A surge

☐ A load

☐ A circuit

☒ A line drop

☐ A charge

Check the statement below which is CORRECT:

In checking the timer of a half-wave rectified machine using a spinning top for $\frac{1}{10}$ of a second the following number of dots should be recorded:

☒ 6 ☐ 12 ☐ 24 ☐ 48 ☐ 60

Check the statement below which is CORRECT:

The pre-reading voltmeter is connected:

☐ In parallel with the x-ray tube
☐ Across the rectifier
☒ Across the primary of the step-up transformer
☐ In the filament circuit
☐ At the midpoint of the secondary of the high-voltage transformer

Check the statement below which is CORRECT:

With a self-rectified unit operating on a 60-cycle circuit the number of impulses of radiation striking the film in $\frac{1}{2}$ second will be:

☐ 15 ☒ 30 ☐ 60 ☐ 120 ☐ 240

Opposite each term in Column 'A' place the number indicating its definition as given in Column 'B'.

	A	B
3	Volt	1. Unit of electrical current
1	Ampere	2. Unit of electrical resistance
2	Ohm	3. Unit of electrical pressure
8	Watt	4. $\frac{1}{1000}$ of an ampere
4	Milliampere	5. 1,000 amperes
7	Kilovolt	6. $\frac{1}{1000}$ of a volt
		7. 1,000 volts
		8. Product of a volt and an ampere

Check the statement below which is CORRECT:

An instrument used to measure electromotive force is:

☐ An ammeter
☐ A microammeter
☐ A watt-meter
☐ An r-meter
☒ A voltmeter

Check the statement below which is CORRECT:

If a valve tube in a full-wave rectified machine burns out, the following will be noticed when an exposure is made:

☐ The milliammeter registers zero
☐ The voltmeter registers zero
☐ There are marked fluctuations in milliamperage
☐ The x-ray tube filament will fail to light up
☒ The milliamperage will be about half the normal amount

Q. Describe the principle and operation of the phototimer on the Morgan-Hodges principle.

A. The phototimer is a combination of a photoelectric cell and various electrical devices which, when incorporated in the primary circuit of an x-ray generator, will terminate the exposure when the desired radiographic density is reached.

Q. What apparatus is used to produce heat in the filament?

A. A filament transformer, sometimes called a Coolidge transformer, plus a filament control, is used to produce heat in the filament.

Q. What governs the milliamperage which passes through an x-ray tube? How is it varied?

A. The current passing through a tube filament will govern the milliamperage. This filament current is varied by means of a variable resistance called the filament regulator or control.

Q. For what purpose is an x-ray transformer used in an x-ray machine?

A. An x-ray transformer is used to generate the high voltage necessary for the passage of current through an x-ray tube.

Q. What is a milliampere-second meter? How is it used?

A. A milliampere-second meter is a milliammeter having a highly damped moving element. It is used to indicate the product of milliampere-seconds in short-time high-milliamperage procedures.

Q. What is the function of the fuse and circuit breaker? What is the difference between them?

A. Fuses and circuit breakers serve to disconnect the x-ray machine from the supply source whenever overloading or shortcircuiting occurs.

The essential difference between them is that a circuit breaker can be manually reset after each opening due to an excessive current, whereas fuses must be completely replaced each time overload causes their breakdown.

Q. If the controls are set for a certain exposure and then the milliamperage is increased—the other setting remaining the same—what is the result on the film produced? Why?

A. The radiographic density of the film will be increased by an amount proportional to the milliamperage increase. This occurs because the density is directly proportional to the milliamperage employed.

Terminology

Match:

2	Beside	1. Pseudo
3	Against	2. Para
1	False	3. Anti
	Upon	4. Pan
5	Around	5. Peri
4	All	

Match:

4	Towards front	1. Cephalic
3	After	2. Dorsal

2	Towards back	3. Post
	Before	4. Ventral
1	Towards head	5. Caudad
5	Towards feet	

Match:

5	Head	1. Caudad
4	Lying face up	2. Prone
	Turn out	3. Flex
1	Tail	4. Supine
3	Bend	5. Cephalad
2	Lying face down	

Opposite each term in Column A place the number of the correct definition as listed in Column B:

2	Anterior	1. Towards the head
8	Medial (mesial)	2. Front
11	Lateral	3. Lying on the side
12	Proximal	4. With the part bent up
1	Cephalad	5. With the part moved away from the body
4	Flexed	6. Below
5	Abducted	7. Above
10	Prone	8. Towards the midline
6	Inferior	9. Towards the tail
13	Sagittal	10. Lying on the abdomen
15	Oblique	11. Away from the midline
3	Lateral decubitus	12. Near the central point of reference
7	Superior	13. Refers to plane which divides the body into right and left parts
		14. Refers to plane which divides the body into anterior and posterior parts
		15. View of part rotated from true A.P. or P.A. position

Therapy and protection

Q. What are the complications to the skin that may develop from x-ray therapy?

A. Redness, blistering, loss of hair, telangiectasia.

Name several different conditions treated with superficial x-ray therapy.

Skin Lesions	*Infections*
a. Basal Cell	*a.* Otitis media
b. Hyperkeratosis	*b.* Furunculosis (boils)
c. Acne	*c.* Pneumonia

d. Squamous cell
e. Warts
f. Keloid (scars)

d. Herpes simplex (fever blisters)
e. Sty

Name several conditions treated with deep x-ray therapy.

Hodgkin's disease
Cancer
Bursitis
Brain tumors
Leukemia
Metastatic bone disease
Herpes zoster (shingles)

Q. What is the difference between a cobalt beam and an x-ray beam?

A. The cobalt beam is made up of two wave lengths. An x-ray beam is a mixture (spectrum) of wave lengths.

Q. What are the signs and symptoms of radiation sickness?

A. Nausea, vomiting, headache.

Q. If you have a copper and aluminum filter, which filter is the exit filter (closest to the patient)? Why?

A. Aluminum: it filters out characteristic rays from copper.

Q. What is meant by the term "half-value layer"?

A. That thickness of material that will absorb 50 per cent of the radiation.

Q. What is the cone?

A. It is a mechanical device used to limit the field of radiation.

Q. What is its purpose?

A. The quantity of scattered radiation may be reduced by using a cone small enough to cover only the part to be radiographed or treated.

Q. What is the purpose of a lead shield?

A. To limit scatter and stray radiation as much as possible.

Q. What is meant by a "hot spot"?

A. An area of overlap from two or more areas of treatment.

Q. What do filters do to an x-ray beam?

A. The greater the filtration the greater the half-value layer; a filter affects the quality by decreasing the wave length of maximum intensity and by decreasing the effective wave length.

Q. Would you expect a skin lesion to require more or less filtration than a bone lesion? Why?

A. Less filtration, because it is not as hard to penetrate.

Check the statement below which is CORRECT:

A thoreus filter is made of layers of:

☒ Aluminum, copper, tin
☐ Aluminum, copper, zinc

☐ Aluminum, copper, brass
☐ Aluminum, copper, lead

Check the statement below which is CORRECT:

The greatest radiation hazard to an embryo or fetus occurs during the:

☐ Period right after delivery
☒ First trimester
☐ Second trimester
☐ Third trimester

Check the statement below which is CORRECT:

The "r" unit is a measurement best suited to determine the:

☐ Quality of radiation
☐ Character of radiation
☒ Quantity of radiation
☐ Amount of gamma radiation

Check the statement below which is CORRECT:

The materials below which are commonly used for protective barriers against radiation are:

☒ Lead
☒ Poured concrete
☐ Polyethelene blocks
☒ Barium plaster

Check the statement below which is CORRECT:

Indicate which of the therapy field sizes given below will result in the greatest absorbed dose:

☐ A round area 10 cm. across
☐ A 10 cm. square area
☐ A rectangle 10 cm. x 15 cm.
☒ A 15 cm. x 15 cm. square area

Check the statement below which is CORRECT:

Beta rays consist of high-speed:

☒ Electrons
☐ Atoms
☐ Neutrons
☐ Protons

Check the statement below which is CORRECT:

The one type of radiation not commonly used in therapy is:

☒ Alpha particles
☐ Isotopes
☐ X-rays
☐ Gamma rays

Check the statement below which is CORRECT:

Check the item below which includes *both* instruments commonly used to measure gamma radiation:

☒ Ionization chamber and Geiger counter
☐ Geiger counter and ammeter

☐ Electrometer and voltmeter
☐ Galvanometer and Geiger counter

Check the statement below which is CORRECT:

The item below which will *increase* the radiation exposure to the patient's skin is the:

☐ Use of a cone
☐ Addition of aluminum filters
☐ Use of high Kv.P. and low Ma.S. technique
☒ Use of low Kv.P. and high Ma.S. technique

Check the statement below which is CORRECT:

The tissue listed below which is *most* sensitive to x-radiation is the:

☐ Brain
☐ Muscle
☒ Gonads
☐ Skin

Q. What are the chief dangers to the operator in a radiographic department where general radiographic work is done?

A. The chief dangers to the operator in a radiographic department are exposure to the radiation coming directly from the x-ray tube and exposure to the secondary and scattered radiation coming from the patient during an x-ray exposure.

Q. How do you protect yourself from stray radiation?

A. Stand behind a lead screen or, if a lead screen is not provided, stay at least 10 feet or more away from the patient during an exposure. If suitable lead screening is not provided, use radiographic cones of sizes just large enough to cover the part being radiographed. This will help to limit scattered and stray radiation from the patient.

Q. How much radiation can be given a patient with safety in radiographic work?

A. It is generally safe to expose a patient to about 2400 milliampere seconds, 85 Kv.P. at 30 inches, using only the inherent filtration of the tube. This figure must be lowered to about 1790 milliampere seconds for head work. If the patient receives the amounts of radiation mentioned, a period of 4 weeks should elapse before additional radiographs are taken.

Q. What are "scattered rays"? What measure can be taken to reduce their effect?

A. Scattered rays are the x-rays that are given off by anything in the path of the primary x-ray beam during an exposure. The main sources are the patient and the x-ray table. The quantity of scattered radiation may be reduced by using a cone small enough to cover only the part to be radiographed. The smaller the area of the primary beam, the less scattered radiation produced.

Q. What milliamperage is usually employed for fluoroscopic work?

A. Usually from one to five milliamperes are employed for fluoroscopic work.

Q. If you were operating the x-ray machine during radiation therapy, what would your duties be during the period of treatment?

A. During the treatment periodically check the positioning of the patient, making sure that no change in position has occurred. A constant check of the x-ray machine factors is also necessary so that proper dosage is given. Should the x-ray factors or patient-position change, corrections must be made immediately. CAUTION: do not attempt to reposition the patient without first turning off the x-ray unit.

Q. If an "r" meter is used to indicate the amount of x-ray being given, is a milliammeter necessary? Why?

A. Yes. Both meters are generally employed as a double check on the quantity of radiation being given to the patient. The Ma. meter is also used to set the machine for the desired exposure factors and used when calibrating the output of the generator.

Q. In handling filters what precautions should be taken before starting treatment?

A. Double check the filters in position for the treatment against the filters called for in the treatment being given to the patient. Request that the radiologist also carefully check the filters being used before treatment is started.

Q. What methods do you employ in checking the correct filter in therapy?

A. Visual inspection of the filters in the filter box, checking the filters by the indicating system on the control panel and/or by the "r" output as indicated by the dosage meter on the control panel against the treatment as described by the radiologist.

Q. What means are used for restricting the radiation to the desired areas?

A. Lead or leaded protective material, cones, or diaphragms, and the correct target-skin distance.

Q. What kind of dressing, ointments, solutions, etc., should be avoided on the skin in areas that are to be treated?

A. It is generally a good rule that all dressings, ointments, and solutions should be avoided unless specifically approved by the radiologist.

Q. What information (technical factors) is necessary to keep your therapy record?

A. The dose in "r" units, the Kv.P., Ma., length of treatment time, target-skin distance, filters and cones employed.

Q. How are the quantity and quality of radiation recorded?

A. Quantity—checked by ionization means. A Victoreen r-meter is generally used. Quality—checked by absorption in some metal, the metal generally being the same as the added filter material. The quality is thus checked by the amount of added filter required to reduce the given intensity by half or to the "half-value layer."

Q. Define: Depth dosage, erythema dose, radiation sickness, epithelioma, wave length.

A. Depth dose—amount of radiation absorbed at the desired depth in the body.

Erythema dose—amount of radiation necessary to produce a noticeable skin reaction.

Radiation sickness—general systemic disorder produced by the destruction of irradiated tissue.

Epithelioma—a malignant tumor consisting mainly of epithelial cells and primarily derived from the skin.

Wave length—since radiation is generally considered to be a wave disturbance it must have a wave length. The length of one wave is the linear distance, in the direction of propagation, between two points of the disturbance which are in the same phase; that is, the distance, for example between successive crests or troughs, so to speak, of the disturbance.

Check the statement below which is CORRECT:

The following devices are not used in measuring the adequacy of x-ray protection:

☐ Film badges
☐ Minometers
☒ Voltmeters
☐ Ionization chambers
☐ Dental films

Check the statement below which is CORRECT:

The safe tolerance amount of whole body radiation per week is about:

☐ 3.0 roentgens
☐ 10.0 roentgens
☐ 100.0 roentgens
☒ 0.3 roentgens (300 milliroentgens)
☐ 0.001 roentgens (1 milliroentgen)

Q. Why does the radiotherapist prefer two parallel opposed ports to one single port if the tumor is located in the midpelvis?

A. With two parallel ports more radiation is given to the tumor than to the skin.

Q. Which machine gives more backscatter on the skin, the cobalt-60 or the 250-Kv. machine?

A. The 250-Kv. machine.

Q. What will the treatment time be in minutes and seconds for 365 r if you have

Field size: 10 x 15 cm.
TSD: 85 cm.
Output on surface: 73 r/min.

A. 5 min.

Q. If the depth dose percentage at 6 cm. is 73.3 per cent and the patient received 785 r to the surface, how many r has the patient received at 6-cm. depth?

A. 575.4 r (rounded off).

Q. Which of the following ports would have to have the shorter treatment time to deliver the same surface dose, a 6 x 10-cm. port or a 10 x 12-cm. port?

A. The 10 x 12-cm. port.

Q. How would you change your treatment time to give the same surface dose if you doubled the TSD?

A. Four times the treatment time (inverse square law).

Q. A patient is being treated on a cobalt-60 machine and has a bandage 5 mm. thick within the treated area. Where will the maximum dose be?

A. To the skin.

Q. What is the advantage of using a wedge?

A. The wedge helps prevent a "hot spot" in an area and gives uniform dosage throughout the treated area. For example, a wedge is used in treating the tonsil, which is not located in the center of the neck but to one side.

Q. Why is the surface dose always larger than the air dose?

A. The surface dose is the result of the air dose plus backscatter, whereas the air dose is only the dosage at a given point in the air.

Q. What does the filter on the superficial machine do to the beam?

A. The filter on the superficial machine screens out the soft rays, thus hardening the beam and giving more penetration.

Anatomy

Q. To what joints are the following related: malleolus, glenoid fossa, condyles, acetabulum, tuberosities?

A. The malleolus is related to the ankle: the glenoid fossa, to the shoulder; the condyles, to the knee, elbow, and occipital; the acetabulum, to the hip; the tuberosities, to the shoulder and hip.

Q. Where is the atlas? malar bone? mandible? maxillae? manubrium?

A. The atlas is the first vertebra or segment of the vertebral column; the malar bone is located on the left and right side of the face or cheek; the mandible is the body of the lower jaw; the maxillae form the upper jaw; and the manubrium is the upper portion of the sternum.

Q. Where is the axis? petrous portion of the temporal bone? acromion process? ilium? zygoma?

A. The axis is the second cervical vertebra; the petrous portion of the temporal bone is the pyramidal portion of the temporal bone extending inward toward the median plane; the acromion process is the distal portion of the spine of the scapula; the ilium is the larger portion of the innominate or hip bone; and the zygoma is the arch of bone extending from the malar or cheek bone to the temporal bone on either side of the skull.

Q. Where is the sacroiliac articulation? brim of the acetabulum? first metacarpal? greater trochanter of the femur? patella?

A. The sacroiliac articulation is located at the junction of the sacrum and the ilium; the superior brim of the acetabulum is located at the edge or border of the cavity that receives the head of the femur; the first metacarpal is between the carpus and the phalanges; the greater trochanter of the femur is located at the upper end of the lateral surface of the femur; the patella is located anteriorly to the knee joint.

Q. Where is the outer canthus of the eye? internal auditory canal? foramen magnum? gallbladder? calcaneus?

A. The outer canthus of the eye is the outer junction of the upper and lower lid of the eye; the internal auditory canal is at the apex of the petrous bone; the foramen magnum is located in the floor of the skull between the occipital bone and the basilar portion; the gallbladder is usually on the right side of the abdomen on the under surface of the liver; and the calcaneus is the heel (also called os calcis).

Q. Where are the kidneys? liver? duodenum? urinary bladder? hepatic flexure?

A. The kidneys are located on the right and left side of the vertebral column, between the eleventh thoracic vertebra and the third lumbar vertebra; the liver is in the upper part of the abdomen, the main portion being on the right side; the duodenum lies between the pylorus and the jejunum; the urinary bladder is in the anterior part of the pelvic cavity; the hepatic flexure is located at the bend of the colon at the junction of its ascending and transverse parts.

Q. Where is the appendix? cecum? spleen? sigmoid flexure? tibia?

A. The appendix is an extension of the cecum; the cecum is the dilated intestinal pouch forming the first part of the large intestine; the spleen is in the upper part of the abdominal cavity and lateral to the cardiac end of the stomach; the sigmoid flexure is the part of the colon between the descending colon and the rectum; and the tibia is the inner and larger bone of the leg below the knee.

Q. Name the bones of the face.

A. The bones of the face are two nasals, two superior maxillae, one mandible, two zygomata, one vomer, two lacrimals, two turbinates, and two palatines.

Q. What are the mastoid cells and in what portion of what bone do they lie? What relation do they bear to a major anatomic landmark?

A. The mastoid cells are the cellular portion of the temporal bone lying at the mid-posterior portion of it. They are usually found posterior to the auditory canal.

Q. How many teeth are in the adult mouth and what are they?

A. There are 32 teeth in the adult mouth. They are eight incisors (four centrals, four laterals), four cuspids, eight bicuspids, and twelve molars.

Q. What is the location of the esophagus? Where does it begin and where does it end?

A. The esophagus is the muscular canal extending from the pharynx to the stomach in the mid-sagittal plane.

Q. Name the three major divisions of the small intestines.

A. The three major divisions of the small intestines are the duodenum, the jejunum, the ileum.

Q. What is meant by the hypochondrium? epigastrium? iliac region? hypogastrium? lumbar area?

A. The hypochondrium is the upper lateral region of the abdomen below the lowest rib; the epigastrium is the upper middle portion of the abdomen over or in front of the stomach; the iliac region is the lower lateral region of the abdomen; the hypogastrium is the lower median anterior portion of the abdomen; the lumbar area is the mid-lateral anterior portion of the abdomen.

Q. Name the main divisions of the urinary tract.

A. The main divisions of the urinary tract are the kidneys, ureters, urinary bladder, and urethra.

Q. Where is the symphysis pubis? xyphoid process? external occipital protuberance? iliac crest? parietal bones?

A. The symphysis pubis is the junction of the pubic bones; the xyphoid process is the extension downward of the sternum; the external occipital protuberance is found on the occipital bone at the junction of the median and nuchal lines; the iliac crest is the lateral, superior portion of the innominate bone; and the parietal bones are the bones which form the posterior and lateral portion of the walls of the neural cranium.

Q. What main anatomical structures lie in the lower right quadrant? upper right quadrant? lower left quadrant? upper left quadrant? pelvis?

A. Lower right quadrant—terminal ileum, cecum, part of ascending colon, appendix. Upper right quadrant—hepatic flexure, liver, right kidney, gallbladder, cystic or common duct, portion of pancreas, occasionally the duodenal cap, second portion of duodenum, some loops of the small bowel, right half of transverse colon. Lower left quadrant—sigmoid colon, portion of descending colon, some loops of small bowel. Upper left quadrant—spleen, left half of transverse colon, greater part of pancreas, stomach, splenic flexure, portion of descending colon, third portion of duodenum, left kidney, portion of jejunum. Pelvis (female)—uterus, ovaries, rectum, and bladder; (male)—rectum and bladder.

Q. Define the following terms: supine, saggital plane, distal, occlusal, thorax.

A. Supine—lying on the back; sagittal plane—a plane running in an antero-posterior direction; distal—farthest from the center, origin, or head; occlusal—the masticating surfaces of molar and bicuspid teeth; thorax—the part of the body between the neck and the abdomen.

Match:

3 Scapula
6 Axis
5 Frontal bone
7 Wrist
1 Maxilla
___ Temporal bone
2 Foot
4 Pelvis
8 Sternum

1. Alveolar ridge
2. Os calcis
3. Coracoid
4. Acetabulum
5. Glabella
6. Odontoid
7. Carpal
8. Xiphoid

Match:

3 Temporal bone
4 Knee joint
___ Sacrum
5 Scapula
6 Pelvis
1 Occipital bone
7 Ankle joint
___ Hand

1. Foramen magnum
2. Manubrium
3. Mastoid cells
4. Patella
5. Glenoid cavity
6. Pubis
7. Malleolus

Match:

3 Frontal
1 Temporal
4 Occipital
2 Sphenoid
8 Ethmoid
7 Maxillae
6 Mandible
5 Fontanelles
___

1. Petrous
2. Sella turcica
3. Glabella
4. Foramen magnum
5. Lambda
6. Coronoid
7. Antra of Highmore
8. Cribriform plate
9. Coracoid

Match:

4 Sternum
2 Atlas
1 Ankle
5 Lumbar
6 Axis
9 Dorsal
8 Coccyx
3 Scapula
___
___

1. Talus
2. First cervical vertebra
3. Acromion
4. Manubrium
5. Five
6. Second cervical vertebra
7. Seven
8. Four fused bones
9. Twelve
10. Ten

Study Questions

Match:

b	1. Cuboid	a. Cervical spine
f	2. Internal acoustic meatus	b. Foot
d	3. Foramen magnum	c. Ulna
m	4. Anterior nasal spine	d. Occipital bone
l	5. Lunate or semilunar	e. Humerus
k	6. Ischial spine	f. Petrous process
a	7. Atlas	g. Femur
j	8. Ileum	h. Scapula
h	9. Coracoid process	i. Tibia
e	10. Lesser tuberosity	j. Small bowel
		k. Pelvis
		l. Wrist
		m. Maxilla

Match:

j	11	3rd molar (*sample*)	a. temporal	1. Waters
c	5	Frontal sinuses	b. occipital	2. lateral skull
a	12	Mastoids	c. frontal	3. Towne
d	6	Optic foramen	d. sphenoid	4. Fletcher's
a	8	Int. aud. meatus	e. maxillae	5. Caldwell
b	3	Foramen magnum	f. mandible	6. Rhese
e	1	Antra of Highmore	g. ethmoid	7. mento-vertex
d	2	Sella turcica	h. palatine bones	8. Stenvers
f	9	Ramus	i. fontanelles	9. lat. mandible
g	6	Cribriform plate	j. teeth	10. A.P. skull 2
g	7	Crista galli	k. zygomatic bones	11. Dental
				12. Law

Match:

4	Odontoid process	1. Sacrum
5	Glenoid fossa	2. Colon
7	Greater trochanter	3. Pelvis
3	Anterior superior iliac spine	4. Cervical spine
12	Alveolar process	5. Scapula
14	Phalanx	6. Small bowel
9	Carpal navicular bone	7. Femur
2	Sigmoid	8. Sternum
6	Jejunum	9. Wrist
		10. Elbow
		11. Tarsus
		12. Mandible
		13. Patella
		14. Finger

Q. What is meant by the cranium? Name the principal bones concerned in its formation.

A. The cranium means the brain case or pan. The principal bones concerned in the formation of the cranium are the frontal, parietals, occipital, temporals, sphenoid, and ethmoid.

Q. What is meant by medial, lateral, superior, and inferior?

A. Medial refers to the middle of the body, lateral refers to the side, superior refers to the upper, and inferior refers to the lowermost.

Q. What is meant by nasal accessory sinuses?

A. The nasal accessory sinuses are the associated bony cavities found within the bones of the face and cranium. They consist of the frontal, maxillary, sphenoid, and ethmoid sinuses.

Q. How many ribs are there? To what portion of the spine are they attached?

A. There are twenty-four ribs and they are attached to the thoracic portion of the spine.

Q. Name the divisions of the spine and state how many vertebrae compose each division.

A. The following are the divisions of the spine and the number of vertebrae which compose each division: cervical—seven, thoracic—twelve, lumbar—five, sacral—five, and coccygeal—four.

Check the statements below which are CORRECT:

In an examination of the petrous apices the following projections are commonly used:

- ☐ Lordotic view
- ☒ Towne view
- ☒ Stenvers projection
- ☒ Law projection

Place the number preceding each part of the body listed in Column A in the space following the region in Column B in which it can be found:

Column A

1. Foramen magnum
2. Anterior nasal spine
3. Lunate or semilunar
4. Ischial spine
5. Atlas
6. Ileum
7. Coracoid process
8. Lesser tubercle
9. Cuboid
10. Internal acoustic meatus

Column B

9 Foot
____ Ulna
1 Occipital bone
8 Humerus
10 Petrous process
____ Femur
7 Scapula
____ Tibia
6 Small bowel
4 Pelvis
3 Wrist
2 Maxilla
5 Cervical spine

Study Questions

Check the statement below which is CORRECT:

The following organ is in the left upper quadrant:

- ☐ Gallbladder
- ☒ Spleen
- ☐ Appendix
- ☐ Hepatic flexure

Indicate any of the following terms used to describe anatomical landmarks of the lower extremities:

- ☒ Lesser trochanter
- ☐ Greater tuberosity
- ☒ Medial malleolus
- ☒ Lateral condyle

Indicate any of the following located in the skull:

- ☒ Pineal gland
- ☐ Obturator foramen
- ☒ Lacrimal bone
- ☐ Olecranon process

Check the statement below which is CORRECT:

The xiphoid tip is usually located at the level of the:

- ☐ Third lumbar vertebra
- ☐ Fourth thoracic vertebra
- ☒ Tenth thoracic vertebra
- ☐ Ramus of the mandible

Check the statement below which is CORRECT:

The sella turcica serves as a bed for:

- ☐ The pineal gland
- ☐ The suprarenal gland
- ☒ The pituitary gland
- ☐ The sphenoid sinuses

Indicate any of the following diseases that will cause an increase in the density of the bone tissue:

- ☒ Chronic osteomyelitis
- ☒ Paget's disease
- ☒ Metastatic prostate
- ☐ Senility

Fill in the blank:

In the so-called blue baby—a cyanotic child with a congenital heart deformity—the blood is being shunted from the _______ side to the _______ side of the heart.

A. Right to left.

Check the statement below which is CORRECT:

When the anterior pituitary gland produces too much growth hormone after puberty, we have a disease called:

- ☐ Hyperthyroidism
- ☐ Turner's disease

☒ Acromegaly
☐ Cushings disease

Check the statement below which is CORRECT:

With the patient in the anatomical position, the hip joint would be located:

☐ 5 cm. medial to greater trochanter
☐ 5 cm. lateral to the symphysis
☒ 2 in. below the point midway between the symphysis and the anterior superior spine
☐ 2 in. medial to anterior superior spine

Q. Name the three main anatomical portions of a long bone.

A. Diaphysis, metaphysis, and epiphysis.

Q. Name three main functions of the liver.

A. The liver manufactures bile, secretes heparin, and converts glucose to glycogen.

Q. Distinguish between bronchitis, bronchiectasis, and atelectasis.

A. Bronchitis is inflammation of the bronchus; bronchiectasis is dilatation of the bronchus; and atelectasis is collapse of all or part of a lung.

Technique

Check the statement below which is CORRECT:

In making radiographs of the gastrointestinal tract it is of utmost importance to use:

☐ A long distance
☒ A short exposure time
☐ A short distance
☐ A high voltage
☐ A low voltage

Check the statement below which is CORRECT:

Assume that the usual time of exposure for a lateral cervical spine at 72-inch distance is $^1/_{10}$ second. At a distance of 36 inches, leaving all other factors the same, the correct exposure time would be:

☐ $^2/_5$ second
☐ $^1/_{20}$ second
☒ $^1/_{40}$ second
☐ $^1/_5$ second
☐ $^3/_5$ second

Check the statement below which is CORRECT:

Generally speaking an increase of 10 Kv.P. may be compensated for by the following change in exposure time:

☐ The time would be cut $^1/_4$
☒ The time would be cut $^1/_2$
☐ The time would be doubled
☐ The time would be tripled
☐ The time would be increased 5 times

Q. When and why should compression be used in radiography, and what is the effect, if any, on technical procedure?

A. Compression is used in radiography for two reasons: first, to help eliminate motion, and secondly, in the case of obese patients, to compress the fatty tissue or remove it from the field of operation as much as possible. By the use of compression, a part is reduced in density, and we may use a somewhat lower amount of the penetrating factor, usually about 4 kilovolts less. This latter figure will depend upon the amount of compression we are able to apply to the part.

Q. What is magnification and what are the factors affecting it?

A. Magnification is that form of distortion which causes an enlargement of the image upon projection. Magnification is brought about by a short focus-film distance or by a great object-film distance.

Q. What is distortion and what are the factors affecting it?

A. Distortion refers to the change in the shape of an object upon projection, either by elongation or foreshortening. Distortion is brought about by misalignment of the tube, object, and film.

Check the statement below which is CORRECT:

Under 100 Kv.P. the percentage of energy in the cathode stream which is converted into x-rays is:

☐ 80% to 90%
☐ 10% to 20%
☐ 97% to 99%
☒ Less than 1%
☐ 50%

Check the statement below which is CORRECT:

The intensity of x-radiation at any given distance from the source of radiation varies:

☐ Directly with the distance
☒ Inversely with the square of the distance
☐ Inversely with the distance
☐ Directly with the square of the distance
☐ Distance does not change it

Check the statement below which is CORRECT:

The wave length of an x-ray beam is determined by:

☐ The quantity of electrons in the cathode stream
☐ The milliamperage
☐ The voltage in the filament circuit
☒ The kilovoltage
☐ The size of the focal spot

Check the statement below which is CORRECT:

The quantity of x-rays received at a given point is primarily dependent on:

☐ The size of the focal spot
☐ The kilovoltage

☐ The type and size of the target
☐ The use of intensifying screens
☒ The milliampere seconds

Check the statement below which is CORRECT:

An increase in kilovoltage across the tube results in:

☒ Radiation of a shorter wave length
☐ Radiation of a longer wave length
☐ No alteration in wave length
☐ Twice as many impulses per second
☐ Higher milliamperage

Q. State the inverse square law.

A. Intensity of x-radiation varies inversely with the square of the distance.

Q. Define primary and remnant radiation.

A. Primary radiation is the radiation emitted from the tube. Remnant radiation is the radiation that is able to penetrate an object and emerge to expose the film.

Match:

2	c	High Kv.P.	1. 10 Ma.S.	a. high contrast
4	b	High density	2. short wave length	b. much black metallic silver
3	a	Low Kv.P.	3. long wave length	c. low contrast
1	d	Low density	4. 200 Ma.S.	d. little black metallic silver

Check the statement below which is CORRECT:

The principal factor controlling the penetration of x-rays is:

☐ Milliamperage
☐ Time
☐ Distance
☒ Kilovoltage
☐ Wattage

Give the Ma.S. for the following Ma. and time combinations:

50 1. 100 Ma. for $^{1}/_{2}$ sec.
60 2. 200 Ma. for $^{3}/_{10}$ sec.
120 3. 300 Ma. for $^{2}/_{5}$ sec.
2.5 4. 50 Ma. for $^{1}/_{20}$ sec.
6.66 5. 100 Ma. for $^{1}/_{15}$ sec.

Of the ten possible answers below, check the *five* completions which you believe to be correct. As it influences the image in a radiograph, the kilovoltage:

✓ Affects radiographic density.
Affects distortion.
Affects detail.
✓ Affects exposure latitude.
Increases detail.
✓ Affects radiographic contrast.

Eliminates the use of cones.
Decreases distortion.
√ Affects the degree of penetration of the object.
√ Affects the production of fog from secondary radiation.

Q. What are the four most prominent factors when operating x-ray equipment?

A. The four most prominent factors are time, milliamperage, distance, and voltage.

Check the statement below which is CORRECT:

The term 'density' when applied to a radiograph refers to:

☐ The sharpness and clearness of the shadow
☐ The distortion of the true shape of the object
☒ The over-all blackness of the radiograph
☐ The degree of difference between the light and dark portions of the film
☐ The thickness of the emulsion on the film

Q. What factors in an x-ray exposure must be changed to produce increased density?

A. Increased radiographic density may be produced by increasing milliampere seconds or voltage.

Q. When good radiographic detail cannot be secured because of inability to approximate the part close to the film, what change in technique may be employed to obtain better detail?

A. When close approximation of the part to the film cannot be secured, the focus-film distance can be increased in order to obtain better detail.

Q. What is the importance of focus-film distance in radiographic technique?

A. The importance of focus-film distance is the fact that it is the controllable factor of detail. Too close a focus-film distance would produce magnification of a part; too great a focus-film distance would cause undue strain on the equipment. Hence, a proper focus-film distance (25 to 40 inches) for most radiographic work is important. The usual focus-film distance in chest radiography is 72 inches.

Q. What is the reason for using very rapid exposures in the examination of the chest?

A. The reason for using very rapid exposures in examination of the chest is to eliminate motion both from respiration and as much as possible from heart action.

Q. What is the reason for using very rapid exposures in the examination of the stomach?

A. The reason for using very rapid exposures in examination of the stomach is to eliminate or minimize motion caused by the peristaltic action of the stomach.

Q. What is the purpose of using a six- or seven-foot focus-film distance in the examination of the heart?

A. The purpose for using a six- or seven-foot focus-film distance in examination of the heart is to minimize magnification which is caused by the increased part-film distance.

Q. What is meant by the following terms and how would you correct the same? Overpenetration? Underpenetration?

A. Overpenetration is the result of using a kilovoltage in excess of the value necessary to produce the desired density in the radiograph. It is corrected by reducing the Kv.P. the necessary amount.

Underpenetration is the result of using a Kv.P. less than the value necessary to produce a satisfactory density. It is corrected by increasing the Kv.P. the necessary amount.

Q. Given a set of exposure factors for an x-ray examination of an adult chest, what changes, if any, would you make in an examination of a small child's chest?

A. If it had to be done this way, one should begin by lowering the milliampere seconds approximately 50 to 60 per cent. If the milliampere seconds could not conveniently be lowered, work from the kilovoltage angle.

Check the statements below which are CORRECT:

The sharpness of detail in a radiograph is dependent on:

☐ The milliampere seconds
☒ The size of the focal spot
☒ The focus-film distance
☒ Immobilization
☒ The object-film distance

Check the statement below which is CORRECT:

Magnification distortion is used to advantage in making good radiographs of:

☐ The heart
☐ The femoral neck in lateral projection
☐ The gallbladder
☒ The temporomandibular joint
☐ The shoulder

Q. What is the relation of Ma. to time of exposure?

A. The Ma. is inversely proportional to the time of exposure. The relationship may be expressed in the following formulas:

$$\text{New Ma.} = \frac{\text{old Ma.} \times \text{old time}}{\text{new time}}$$

$$\text{New time} = \frac{\text{old time} \times \text{old Ma.}}{\text{new Ma.}}$$

Q. What formula might be used to find the size of field to be covered by a cone?

A.

$$\text{Size of field} = \frac{\text{target film distance} \times \text{lower diameter of cone}}{\text{distance from target to lower edge of cone}}$$

Check the statement below which is CORRECT:

The following greatly affects the maintenance of density in radiography of the chest:

☐ Short exposure time
☐ Immobilization of the patient
☐ Kv. P.
☒ Air content of lungs
☐ Use of correct focal spot size

Check the statement below which is CORRECT:

When using a technique below 85 Kv.P., if an 8-to-1 grid is replaced by a 16-to-1 grid, the Kv.P. should be increased approximately:

☐ 2 Kv.P.
☒ 6 Kv.P.
☐ 12 Kv.P
☐ 16 Kv.P.

Check the statement below which is CORRECT:

High Kv.P. is required when radiographing structures of greater density in the body chiefly because of the:

☒ Absorption of radiation that results
☐ Electrons absorbed by inherent filtration
☐ Electrons absorbed by the part
☐ Penetrating effect of the longer wave lengths

Check the statement below which is CORRECT:

If I were a patient, I would rather a technologist used the following exposure to radiograph my lumbar spine:

☐ 70 Kv.P., 200 Ma.S.
☐ 84 Kv.P., 100 Ma.S.
☐ 100 Kv.P., 50 Ma.S.
☒ 120 Kv.P., 25 Ma.S.

Check the statement below which is CORRECT:

Useful radiographic densities lie within a range of:

☐ 1 to 3
☐ .1 to .5
☒ .25 to 2.5
☐ 4 and above

Check every statement below which is CORRECT:

True distortion on the radiograph is the function of:

☐ Focal spot size
☐ Focus-film distance
☒ Film, part, tube alignment
☐ Part-tube distance

Q. Will the sharpness of detail *increase, decrease,* or *remain the same* if (*a*) par speed screens are used instead of high? (*b*) the part-film distance is 6 inches instead of 3? (*c*) the Kv.P. is increased by 10? (*d*) the focal spot is 1 mm instead of 2 mm? (*e*) focus-film distance is increased from 40 to 72 inches?

A. (*a*) Increase, (*b*) decrease, (*c*) same, (*d*) increase, (*e*) increase.

Check every statement below which is CORRECT:

Absorption of x-rays is influenced by:

☒ Atomic weight
☒ Ma. used
☐ Temperature of the screen
☒ Thickness of the part
☐ Speed of the ray employed
☒ Wave length of the radiation produced
☒ Kv.P. used

Check any statement below which is CORRECT:

Radiographic fog increases as:

☒ Tissue volume increases
☐ Part moves closer to film
☐ Total quality of primary radiation is reduced
☒ Body part is predominantly soft tissue

Check every statement below which is CORRECT:

Radiographic contrast is the result of:

☐ Focal spot used
☒ Kv.P. used
☒ Volume of tissue
☒ Condition of tissue

Check the statement below which is CORRECT:

The factor which produces the greatest unsharpness is:

☐ Focal spot size
☐ Large focus-film distance
☒ Motion
☐ High-speed screens

CHECKLIST FOR RADIOGRAPHIC QUALITY

Detail

1. *Sharpness* of Detail (Definition)
    A. Motion
        i. voluntary
            a. immobilization
        ii. involuntary
            a. exposure time

B. Projection
  - *i.* size of focal-spot
  - *ii.* object-film distance
  - *iii.* focus-film distance

C. Physical Factors
  - *i.* film holder
    - *a.* cardboard holder—direct exposure
    - *b.* cassette and intensifying screens—indirect exposure
      - (*1*) type and speed of screens
      - (*2*) film-screen contact
  - *ii.* film resolution

2. *Visibility* of Detail (Photographic)
  - *A.* Density
  - *B.* Contrast
  - *C.* Processing

Density	*Contrast*
Ma.S.	Kv.P.
(quantitative)	(qualitative)
Thickness of part	Fog
Tissue opacity	Cone—grid
Pathology	Intensifying screens
Respiration	Filtration
Distance	Film characteristics

Processing
Efficiency of equipment

Magnification

1. Object-film distance
2. Focus-film distance

Distortion

1. Alignment of tube-object-film

Superimposition

1. Opacities of surrounding structures
2. Alignment of tube-object-film

Special procedures

Opposite each procedure in Column A place the number of the region where it is used as listed in Column B:

11 Venogram (phlebogram)
8 Myelogram
12 Pneumo-encephalogram
4 Sialogram
6 Cholangiogram
10 Cholecystogram
13 Carotid angiogram
2 Bronchogram
1 Salpingogram
5 Excretory urogram

1. Fallopian tubes
2. Lungs
3. Heart chambers
4. Salivary ducts
5. Renal calyces and pelves
6. Bile ducts
7. Aorta
8. Spinal canal
9. Knee joint
10. Gallbladder
11. Veins of the extremities
12. Ventricular system
13. Arteries of the brain

Opposite each procedure in Column A place the number of the region or purpose for which it is used in radiographic visualization as listed in Column B:

12 Cholangiography
4 Bronchography
3 Myelography
5 Uterosalpingography
13 Ventriculography
1 Photofluorography
2 Venography
6 Cholecystography
14 Body-section radiography
7 Pelvimetry

1. Fluoroscopic images
2. Veins
3. Spinal canal
4. The bronchial tree
5. The uterus and fallopian tubes
6. The gallbladder
7. The birth canal
8. The chambers of the heart
9. The arteries of the brain
10. The urinary tract
11. The abdominal aorta
12. The biliary ducts
13. The fluid-containing spaces of the brain
14. Regions at a predetermined depth

Opposite each procedure listed in Column A place the number of the region where it is used as listed in Column B :

13 Uterosalpingogram
6 Angiocardiogram
11 Aortogram
3 Teleoroentgenogram
4 Cerebral angiogram
7 Ventriculogram
9 Bronchogram

1. Skull
2. G. I. tract
3. Chest for heart size
4. Arteries of the brain
5. Spinal canal
6. Chambers of the heart
7. Ventricles of the brain

1 Towne's view or position

10 Intravenous urogram

8. Veins of the extremities
9. Bronchial tree
10. Urinary tract
11. Aorta
12. Hip
13. Female genital tract

Check the statement below which is CORRECT:

Rapid filming methods are advantageous in the following study:

☒ Aortography
☐ Ventriculography
☐ Pneumoarthrography
☐ Retro-peritoneal air studies

Positioning

Check the statement below which is CORRECT:

In the lateral projection of the scapula:

☐ The coracoid process is centered to the film
☒ The central ray is aligned at 90 degrees to the vertebral border of the scapula
☐ The patient is placed in a lateral decubitus position
☐ The glenoid cavity is best demonstrated

Check the statement below which is CORRECT:

The best position to show the articular facets of the lumbar spine is the:

☒ Oblique
☐ A.P.
☐ Lateral
☐ P.A.

Check the statement below which is CORRECT:

The external auditory meatus is used as a landmark to locate the:

☒ Sella turcica
☐ Maxilla
☐ Frontal sinus
☐ Nasion

Check the statement below which is CORRECT:

The best position to demonstrate the clavicle in an adult is the:

☐ A.P. position with caudal angulation
☐ A.P. position with a perpendicular ray
☒ P.A. position
☐ Lateral position

Check the statement below which is CORRECT:

The A.P. projection of the skull with a 30–35 degree caudal angulation demonstrates primarily the:

☐ Sphenoid bone
☐ Frontal bone

☒ Petrous ridge
☐ Parietal bone

Check the statement below which is CORRECT:

The anterior superior iliac spine is used as a landmark in locating the point of entry of the central ray when making a radiograph of the:

☒ Sacrum
☐ Shoulder
☐ Sternum
☐ Gallbladder

Check the statement below which is CORRECT:

An occlusal film is placed in the mouth with a portion extending from the mouth. The central ray is projected downward perpendicular to the film. This view best demonstrates:

☒ The nasal bone
☐ The palatines
☐ The mandibular symphysis
☐ Wharton's duct

Check the statement below which is CORRECT:

When the patient is in the frog-leg position, the thighs are placed in:

☐ Full adduction
☒ Full abduction
☐ Full extension with the feet together
☐ Full flexion over the abdomen

Check the statement below which is CORRECT:

In mitral stenosis the position that best demonstrates the left atrium of the heart is the

☐ Right lateral
☐ Left anterior oblique
☐ A.P. position
☒ Right anterior oblique

Check the statement below which is CORRECT:

When radiographing the ankle in the antero-posterior projection on a single film, the

☐ Heel is placed in the center of the film
☒ Inter-malleolar plane is parallel to the film
☐ Ankle is rotated laterally 5 degrees
☐ Central ray is angled 10 degrees cephalad

Six bony prominences are listed below. Opposite each one listed place a YES if it can be felt through the skin and a NO if it cannot.

YES	Greater trochanter
NO	Body of the ninth thoracic vertebra
NO	Lesser trochanter
YES	Symphysis pubis
YES	Acromion process
YES	Manubrium

Check the statement below which is CORRECT:

When radiographing the coccyx in the antero-posterior position, the central ray is directed:

☐ Perpendicular to the film
☐ Cephalad
☒ Caudad
☐ To a point 2 inches below the pubis

Check the statement below which is CORRECT:

In the Chamberlain-Towne position, the central ray is directed so that the orbito-meatal line forms an angle with the central ray of:

☐ 60°
☒ 30°
☐ 20°
☐ 45°

Check the statement below which is CORRECT:

A long exposure time can be used to advantage in a technique intended to show:

☐ The stereoscopic lung field
☐ Kidney, pelvis, and ureters in an IVP
☐ A stomach with barium
☐ The gallbladder
☒ The lateral thoracic spine

Check the statement below which is CORRECT:

A routine P.A. chest radiograph is taken at a six-foot target-film distance in order to:

☐ Increase contrast
☐ Increase magnification
☐ Decrease detail
☒ Decrease magnification
☐ Stop motion

Q. In radiography of the lower dorsal spine in the anteroposterior position, why is it desirable to center to the sixth dorsal vertebra?

A. In order to take advantage of the divergent rays for separating the joint spaces and also to equalize density over the entire section of the spine being examined.

Q. In radiography of certain areas of the body, very close focus-film distance may sometimes be desirable. Name one such area and give the reason.

A. An area of the body where very close focus-film distance might be desirable, at times, is the atlas and axis. Such a procedure may be followed in order to obtain magnification of the part and blur out the superimposed parts.

Q. What is the Waters-Waldron position and where is it used?

A. The Waters-Waldron position is used in examination of the maxillary sinuses. The patient is prone, head resting on the chin, cantho-meatal line forming an angle of 37° to the perpendicular, central ray perpendicular to the film and entering the head at the vertex, passing just in front of the ear and making its exit at a point in line with the junction of the nose and upper lip. The median plane of the head is perpendicular to the table top.

Q. What is the modified Law position and where is it used?

A. The modified Law position is used in examination of the mastoid. The patient is prone, head rotated 15° to either side, central ray is angled 15° toward the face and enters the head about two inches above and behind the unaffected ear to exit through the mastoid closest to the film.

Q. What is the Stenvers position and where is it used?

A. The Stenvers position is used in the examination of the petrous portion of the temporal bone. The patient is in the prone position, median line of the body over the center line of the table. The head is turned at an angle of 45° from the posteroanterior position with the forehead and malar bone touching the cassette. The tube is tilted 12° toward the head, the central ray being directed through the external auditory meatus closest to the film.

Q. What is the Towne position and where is it used?

A. The Towne position is used in the examination of the occipital and petrous bones in an anteroposterior projection. The patient is supine, median line of the head is over center line of the table, the chin is depressed as far as comfortably possible. From the side of the table the film is centered to the occipital protuberance. The tube is angled approximately 30° towards the feet, and the central ray is directed to the center of the film.

Q. What methods are used to secure immobilization of the parts radiographed? Why is immobilization so essential to the successful radiograph?

A. Cloth immobilizing bands, sandbags, padded bricks, or head clamp. Such devices are essential to successful radiography for the elimination or control of motion in order to secure good detail.

Q. What views are ordinarily taken of any part and why?

A. Ordinarily two views at right angles to each other are taken of a part in order to secure proper perspective and relation of the parts to the surrounding tissue or parts. When two views at right angles cannot be secured, we can make stereoscopic views in order to secure depth of vision.

Q. What are spot exposures in gastrointestinal work?

A. Spot exposures are usually from one to four exposures made on a film at intervals of a few seconds for the purpose of obtaining progressive views of stomach or colon peristalsis in gastrointestinal radiography. A special spot-taking device is usually a part of the fluoroscopy unit.

Q. Why is it necessary to have close approximation of the part to the film?

A. It is necessary to have close approximation of the part to the film in order to eliminate an objectionable amount of magnification.

Q. Given a set of exposure factors for an x-ray examination of a co-operative patient, what changes would you make for an unco-operative or irrational patient?

A. Decrease the exposure time to a value sufficiently small to obviate possibility of motion; at the same time increasing the Ma. value by the amount needed to produce the original Ma. value. Alternately, decrease the exposure time to obviate motion and increase the Kv.P. so as to maintain film density.

Q. Describe the effects of inspiration and expiration in radiography of the chest, sternum, dorsal spine, ribs.

A. In radiography of the chest, sternum, ribs, and dorsal spine, films made on inspiration will be more dense than those made on expiration, all other factors being the same. In radiography of the chest, the diaphragm will be lower on inspiration than on expiration.

Check every statement below which is CORRECT:

The positions which may be used most successfully in demonstrating the odontoid process are

- ☒ Conventional lateral view of the cervical spine
- ☒ Exaggerated Waters view ordinarily used for facial bones
- ☒ Open-mouth view
- ☐ Conventional A.P. view of the cervical spine
- ☒ A.P. exposure while moving lower jaw

Check the statement below which is CORRECT:

For a radiograph of the gallbladder of an obese person the central ray is usually directed to enter the body:

- ☐ At a point lower and nearer the spine than for a person of normal weight
- ☐ At a point higher and nearer the mid-line than for a person of normal weight
- ☐ At a point lower and more to the right than for a person of normal weight
- ☒ At a point higher and more to the right than for a person of normal weight
- ☐ At a point behind the spine

Check the statement below which is CORRECT:

The odontoid process is well visualized in the following view:

- ☐ Lateral view of the tarsus
- ☐ Oblique view of the mandible
- ☒ Open-mouth view of the cervical spine
- ☐ Oblique view of the lumbosacral joint
- ☐ Lateral view of the sternum

Check the statement below which is CORRECT:

In an examination of the petrous apices the following projection is not commonly used:

- ☒ Lordotic view
- ☐ Towne position
- ☐ Law projection
- ☐ Arcelin projection
- ☐ Stenvers projection

Check the statement below which is CORRECT:

In making a radiograph of the sinuses using the Waters position, the purpose of the position is to:

☐ Project the sphenoid sinus away from the maxillary sinuses
☒ Project the petrous portions of the temporal bones below the maxillary sinuses
☐ Project the petrous portions of the temporal bones above the maxillary sinuses
☐ Superimpose the petrous portions of the temporal bones on the maxillary sinuses

Check the statement below which is CORRECT:

In making a P.A. radiograph of the abdomen the patient is in:

☒ The prone position
☐ The abducted position
☐ The supine position
☐ The lateral recumbent position
☐ The dorsal decubitus position

Check the statement below which is CORRECT:

In taking a P.A. radiograph of the chest the shoulders are rolled forward to:

☐ Elevate the clavicles
☐ Enlarge the chest
☐ Lower the diaphragm
☒ Remove the scapulae from the region of the lung field
☐ Bring the heart closer to the film

Check the statement below which is CORRECT:

In making a P.A. radiograph of the distal radius and ulna the hand should be placed in:

☐ The lordotic position
☐ Flexion
☐ Supination
☐ The 'anatomical' position
☒ Pronation

Check the statement below which is CORRECT:

In the Waters sinus position the central ray enters the skull in the midsagittal plane emerging at:

☐ The external occipital protuberance
☒ The junction of the upper lip and nose
☐ The external auditory meatus
☐ The base of the nose (glabella)
☐ The mastoid tip

Check the statement below which is CORRECT:

The foramen magnum is best demonstrated by the use of:

☐ Waters position
☐ Stenvers position

☐ Granger position
☐ Law position
☒ Towne position

Check the statement below which is CORRECT:

When one is making a P.A. radiograph of the gallbladder of an average adult patient, the central ray is usually directed so as to enter the body:

☐ At the level of the 12th thoracic vertebra
☒ Three inches to the right of the 2nd lumbar vertebra
☐ Two inches to the left of the 2nd lumbar vertebra
☐ Two inches above the crest of the left ilium

Check the statement below which is CORRECT:

The Stenvers position is used in making a radiograph of:

☐ The sphenoid sinus
☐ The sella turcica
☐ The maxillary sinus
☐ The symphysis menti
☒ The petrous process

Check the statement below which is CORRECT:

When one is making a verticosubmental sphenoid sinus radiograph, the central ray enters at:

☒ The top of the skull
☐ The outer canthus of the eye
☐ The root of the nose
☐ The external auditory meatus
☐ The center of Reid's base line

Check the statement below which is CORRECT:

When one is making a P.A. radiograph of the duodenal bulb of an average adult patient, the central ray is usually directed so as to enter the body:

☐ Two inches to the right of the 12th thoracic vertebra
☐ One inch to the right of the 5th lumbar vertebra
☐ One inch to the right of the 2nd lumbar vertebra
☒ Two inches to the left of the 2nd lumbar vertebra
☐ In the midline at the level of the 9th thoracic vertebra

Check the statement below which is CORRECT:

When one is making an x-ray of the hip in the anterior-posterior projection, the following bony landmarks must be noted:

☒ The anterosuperior spine
☒ The symphysis
☒ The greater trochanter
☐ The patella
☐ The 1st lumbar vertebra

Check the statement below which is CORRECT:

The crest of the ilium is used as a landmark in making:

☐ A radiograph of the A.P. thoracic spine
☐ An A.P. shoulder radiograph

☒ A KUB
☐ A lateral radiograph of the sternum
☐ An A.P. of the os calcis

Check the statement below which is CORRECT:

When making an A.P. radiograph of the wrist the hand should be placed in:

☐ Pronation
☒ The anatomical position
☐ Flexion
☐ Adduction
☐ Eversion

Check the statement below which is CORRECT:

The malleoli are used as landmarks when making a radiograph of:

☒ An A.P. ankle
☐ A P.A. knee
☐ An A.P. shoulder
☐ An A.P. elbow

Check the statement below which is CORRECT:

A long exposure time can be used to advantage in techniques intended to show:

☐ The stereoscopic lung field
☐ Kidney, pelves, and ureters in an IVP
☐ A stomach with barium
☐ The gallbladder
☒ The sternum

Check the statement below which is CORRECT:

In making a radiograph of the gastrointestinal tract it is important to use:

☐ A long target-film distance
☒ A short exposure time
☐ Self-rectified equipment
☐ As low kilovoltage as possible
☐ A thoraesus filter

Check the statement below which is CORRECT:

The amount of tube shift required in making stereoscopic radiographs to be viewed in a standard stereoscope is determined by:

☐ The object-film distance
☐ The milliampere seconds used
☐ The kilovoltage employed
☒ The focus-film distance
☐ The type of x-ray tube used

Check the statement below which is CORRECT:

In a pelvimetry the following is not important in obtaining an accurate measurement:

☐ The part-table distance
☐ The tube-table distance

☐ The distance between table top and film
☒ The kilovoltage used
☐ The centering of the tube

Indicate by number the relative position of the wave lengths of the forms of radiation listed starting with No. 1 for that having the shortest wave length:

_3_ Ultraviolet
_5_ Infrared
_1_ Gamma rays
_4_ Visible light
_2_ X-rays

A GLOSSARY FOR RADIOLOGIC TECHNOLOGISTS

a-, an-. *prefix.* Without; as *atonic,* without tone.

ab-. *prefix.* From; away from.

abdomen. *n.* The body cavity below the chest which contains the abdominal viscera—the stomach, intestines, liver, spleen, etc.; it is separated from the chest by the diaphragm.

abduct. *v.t.* To draw away from the midline, as to abduct an extremity.

abrasion. *n.* The scraping away of a portion of the surface, as of skin or mucous membrane.

abrasion marks. Disfigurement of the emulsion of an x-ray film due to rubbing.

abscess. *n.* A small area of infection causing destruction in the tissues.

absorb. *v.t.* To assimilate (fluids or other substances) from the skin or other body tissues.

absorption spectrum. The resultant spectrum after radiation has passed through some absorbing substance.

a.c. Before meals (ante cibum).

acceleration. *n.* The rate of change of motion or action.

accessory. *adj.* Additional, supplementary.

acetabulum, -a. *n.* The joint cavity in the innominate bone for articulation with the head of the femur to form the hip joint.

achondroplasia. *n.* A bone disease in which cartilage is not properly replaced by bone.

acid. *adj.* Characterized by an excess of negative ions; the opposite of *basic* or *alkaline.*

acid fixing bath. Dilute acetic acid for the immediate stopping of film development.

acoustic nerve. The nerve of hearing.

acrania. *n.* Congenital lack of the cranial bones.

acromegaly. *n.* A disease of the pituitary gland in adults which produces overgrowth of bone, especially of the lower jaw and hands.

acromioclavicular joint. The joint between the clavicle and the acromion process of the scapula.

acromion process. The flat bony process from the upper portion of the scapula which forms the prominence of the shoulder.

actinic radiation. Radiation able to produce chemical change, as the effect of light and x-rays on a photographic emulsion.

actinic rays. The portion of light which affects the photographic emulsion.

actinomycosis. *n.* A fungus infection.

acute. *adj.* Having a sudden onset and a short course.

ad-. *prefix.* To or toward.

adeno-. *prefix.* Pertaining to a gland or glands.

adenoma, -ata. *n.* A tumor of glandlike structure.

adenopathy. *n.* Enlargement of the glands.

adherent. *adj.* Stuck together.

adhesion. *n.* Sticking together of two surfaces due to an inflammatory process, as, for example, the adhesions of the pleura from pleurisy or of the peritoneum from inflammation resulting from operation or peritonitis.

adipose tissue. Fatty tissue.

adnexa. *n.* Organs adjoining.

aer-. *prefix.* Air.

aerated. *adj.* Filled with air.

agenesia. *n.* Complete failure of a part or organ to develop.

A/G ratio. Ratio in blood serum of albumin to globulin.

air bells. Small spherical clear areas on the finished x-ray film due to bubbles of air adhering to the emulsion during development and preventing the action of the developer on these areas.

-algia. *suffix.* Pain.

align, aline. *v.t.* To bring into a straight line.

alimentary canal. A continuous tube which extends from the mouth to the anus.

alkaline. *adj.* Chemically basic, with an excess of positive ions; opposite, *acid.*

alpha particle. A positively charged nucleus of a helium atom emitted spontaneously from radioactive substances.

alveolar process. The bony process which serves as a support for the teeth.

alveolus. *n.* A terminal air sac of the lung.

ambi-. *prefix.* Both; both sides.

ambulatory. *adj.* Walking about.

ammeter. *n.* An instrument for measuring the quantity of an electric current.

amniography. *n.* Roentgenographic examination of the pregnant uterus.

amoeba. *n.* A unicellular organism; some species can infect the colon.

amorphous. *adj.* A plastic state of matter having no regular form.

ampere. *n.* The unit of measurement of quantity of an electric current.

anatomy. *n.* The science which deals with the *normal* structures of the body.

andro-. *prefix.* Pertaining to the male.

anemia. *n.* Lack of normal hemoglobin content in the blood; deficiency of blood in quantity or quality.

anesthesia. *n.* Suspension of sensation in a part or organism.

aneurysm. *n.* An abnormal sacculation or pouching of a blood vessel.

angina pectoris. A condition produced by spasm of the nutrient arteries of the heart, marked by paroxysmal thoracic pain and suffocation.

angio-. *prefix.* Pertaining to a vessel, usually blood or lymph vessels.

angioma. *n.* A blood-vessel tumor. Also *hemangioma.*

anion. *n.* A positively charged ion.

ankylosis. *n.* Complete lack of motion of a joint.

anode-film distance. Focus-film distance.

anomaly. *n.* An unusual variation in the development of a structure or organ.

anorexia. *n.* Want of appetite.

ante-. *prefix.* Before.

anterior. *adj.* Of or at the front of a structure or part.

anthracosis. *n.* A disease of the lungs due to prolonged inhalation of fine particles of coal dust.

anti-. *prefix.* Against.

antrum. *n.* A sinus.

anus. *n.* The external opening of the colon.

aorta. *n.* The large artery which takes the blood away from the heart.

aortitis. *n.* Inflammation of the aorta.

A.P. Antero-posterior; from front to back.

apex, -es or apices. *n.* The point of a pyramidal structure; the upper portion of the lung; the end of a root of a tooth.

apical infection. Infection of the apex of the root (of a tooth).

appendicitis. *n.* Inflammation of the vermiform appendix.

appendix. *n.* A small tubular appendage attached to the cecum at its junction with the small bowel. Also *vermiform appendix.*

apposition. *n.* The bringing of two adjacent surfaces into contact.

arachnoid. *n.* The middle fibrous layer of the meninges covering the brain.

Arceline. *adj.* Of a position for x-ray examination of the mastoids.

arm. *n.* The portion of the upper extremity between the shoulder and the elbow.

armature. *n.* The revolving portion of a motor; a piece of iron placed across the two poles of a magnet.

arterial. *adj.* Pertaining to the arteries or arterial system.

arteries. *n.* The blood vessels which carry the blood from the heart to the peripheral structures of the body.

arteriography. *n.* Roentgenographic examination of arteries after the injection of opaque material.

arteriosclerosis. *n.* Sclerosis or hardening of the arteries.

arthritis. *n.* Inflammation of a joint.

arthritis deformans. *n.* A type of arthritis characterized by pronounced deformity.

arthro-. *prefix.* Pertaining to a joint of bone.

articular. *adj.* Pertaining to a joint.

articular cortex. The end of a long bone over which the articular cartilage extends.

articular facets. Small rounded surfaces for articulation.

articular processes. Processes of bone (as the vertebrae) bearing articular surfaces or facets.

articulation. *n.* A joint surface of a bone.

artifact, artefact. *n.* Artificial marks on an x-ray film due to accidents in handling or processing the film, as *crinkle marks.*

ascending colon. The portion of the colon from the cecum at its connection with the small bowel to the hepatic flexure where it turns.

-ase. *suffix.* Enzyme, ferment.

asthenic. *adj.* (Of the habitus of an individual) lacking normal tone.

asthma. *n.* A spasmodic condition of the respiratory tract causing difficulty of expiration.

astragalus. *n.* The talus.

atelectasis. *n.* The state of an organ when it is devoid of air; as atelectasis of a lung.

atomic number. The number assigned to an element in the periodic table, depending upon the number of electrons revolving about the nucleus.

atomic weight. Weight of an atom of structure compared with the atom of hydrogen which is represented as 1; theoretically, the number of unit positive charges in the nucleus.

atresia. *n.* The narrowing of an opening of a passage or tube.

atrophic arthritis. An involvement of a joint associated with atrophy of the tissues.

atrophy. *n.* Wasting away of a tissue or part.

atypical. *adj.* Not typical; of unusual type.

auditory meatus. The opening of the external ear.

auricle of the ear. The cartilaginous flap of the ear.

auricles of the heart. Right and left chambers of the heart which receive the blood from the body and pulmonary circulation.

auricular. *adj.* Pertaining to the ear or to the auricles of the heart.

autotransformer. *n.* A piece of electrical apparatus consisting of a single coil of wire wound about a core of iron, connected across an alternating current circuit, with taps taken off the coil at convenient intervals connected to buttons which are conveniently arranged so that more or less of the coil can be subtended in a secondary circuit, the purpose of which is to maintain the voltage over wide variations of the amperage up to the capacity of the generator.

axilla. *n.* The armpit.

azygos. *adj.* Unpaired; as the azygos lobe of the lung, an anomalous accessory division of the upper portion of the right lung caused by persistence of the azygos vein from fetal life.

bacillus. *n.* A rodlike microscopic organism.

ballistic milliampere meter. A meter designed to read in milliampere seconds for measuring extremely short exposures (less than one second) where a high milliamperage is necessary; for instance, in radiographic work, exposures of less than one second, with 100 Ma. or more.

barium meal. A test meal to which barium sulfate has been added so as to render visible the gastrointestinal tract.

battery (electric). *n.* A collection of electric cells. They may be connected in series, multiple, or parallel circuits.

Bechterew's spondylitis. A disease of the spine resulting in complete ankylosis.

Becquerel rays. The rays emitted from uranium compounds.

benign. *adj.* Innocent; not malignant.

Bennett's fracture. A fracture of the proximal end of the metacarpal bone of the thumb.

Benoist penetrometer. A circular metallic ladder of different thicknesses of aluminum, from 1 to 10 mm., conveniently arranged so that densities cast by varying thicknesses of the aluminum ladder can be compared to that cast by a thin central disc of silver; used to judge the relative penetration of the x-ray beam.

beta "rays." Electrons spontaneously emitted by radioactive substances in their natural process of decay.

bi-. *prefix.* Two.

biceps muscle. The powerful flexor muscle forming the prominence on the anterior aspect of the arm.

bicuspids. *n.* Upper and lower teeth located between the cuspid and the molars, each having two cusps, i.e., proturberances.

bifurcate. *v.t.* To branch or divide.

bifurcation. *n.* Division into two branches.

bilateral. *adj.* On both sides.

bile ducts. *n.* The tubes which collect the bile and convey it to the gallbladder and intestine.

biophysics. *n.* The science which deals with the physical processes of living tissues.

bladder (urinary). *n.* The distendable muscular pouch or sac which serves as a reservoir for urine poured into it from the ureters.

blast-. *prefix and suffix.* Germ, bud.

blastomycosis. *n.* A fungus infection.

blisters. *n.* Rounded raised areas on any surface; in photography, raised areas on the surface of the film due to separation of the photographic film from the basic celluloid sheet.

BMR. Basal metabolic rate.

body of a vertebra. The heavy spongy portion of the vertebra which forms the main support of the spine.

bones. *n.* Classifications: long, as bones found in the extremities; short, as bones of hands and feet; flat, as bones of the skull; irregular, as vertebrae; sesamoid, as small rounded bones found in the tendons.

BP. Blood pressure.

BPH. Benign prostatic hypertrophy.

brachy-. *prefix.* Short.

brachycephaly. *n.* Unusual shortness of the skull.

brady-. *prefix.* Slow.

Brodie's abscess. A small painless abscess in bone.

bronchiectasis. *n.* A condition in which there is prominent saccular dilatation of the bronchi.

bronchioles. *n.* The smaller subdivisions of the bronchi.

bronchitis. *n.* Inflammation of the air tubes which supply the lung.

broncho-. *prefix.* Pertaining to bronchial tubes.

bronchogenic. *adj.* Having origin from a bronchial structure.

bronchography. *n.* Roentgenographic examination of the chest after injection of opaque solution.

broncholithiasis. *n.* A condition in which stones are formed in the air passages of the lungs.

bronchopneumonia. *n.* A type of lung infection which spreads to the lungs from the bronchi.

bronchostenosis. *n.* Narrowing or constriction of a bronchus.

bronchus. *n.* Any of the air tubes which supply the lung.

Bucky diaphragm, Potter-Bucky diaphragm. A piece of roentgenographic apparatus consisting of a grid of parallel strips of lead, the purpose of which is to reduce the effects of scattered radiation.

bulbous. *adj.* Expanding into a bulblike structure.

bumper fracture. A compression fracture of the upper end of the tibia caused by impact of an automobile bumper with the side of the knee.

bunion. *n.* A thickening of the bursa over the great toe.

bursa. *n.* A small pouchlike sac overlying bony prominences or tendons to prevent friction due to movement of the part.

bursitis. *n.* Inflammation of a bursa.

buttocks. *n.* The large rounded gluteal prominences.

c̄. With (*cum*).

C. Centigrade.

CA. Carcinoma.

calcaneus. *n.* Heel bone. Also *os calcis.*

calcicosis. *n.* A disease of the lungs caused by inhalation of fine particles of calcium dust.

calcification. *n.* The laying down of calcium salts in a tissue.

calcinosis. *n.* The deposit of calcium salts in soft tissues in locations where they are not normally found.

calcium salts. Chiefly calcium phosphate and calcium carbonate, which are deposited in bony structure.

calculus. *n.* Stone.

calibration (of an x-ray machine). *n.* Charting the voltage output for various buttons of the autotransformer, at various milliamperages.

callus. *n.* The plastic material which is thrown out by nature around the ends of broken bones.

calorie. *n.* The unit of heat; the amount of heat necessary to raise the temperature of one gram of water one degree centigrade (small calorie).

calorimeter. *n.* An instrument or apparatus for the measurement of calories.

calyx, calix, -ces. *n.* One of the small funnel-shaped structures into which the renal capillaries dip for the separation of urine.

canal. *n.* An open passageway.

cancellous bone. The spongy, soft portion of the ends of a long bone.

cancer. *n.* Any malignant new growth of cells.

candle power. The unit of intensity of illumination; for instance, a 16-candle-power electric bulb.

canthus. *n.* The angle between the upper and lower eyelids.

capacity. *n.* The full extent to which an electrical condenser can be charged; an actual charge on any electrode.

capillaries. *n. pl.* The minute terminal blood vessels which end in the body tissues.

capit-. *prefix.* Pertaining to the head.

capitellum. *n.* The outer portion of the articular surface of the lower end of the humerus for articulation with the head of the radius.

capsule of a joint. The fibrous tissue ligaments which form a surrounding cover for the joint.

carcinoma. *n.* Cancer of epithelial origin.

cardia. *n.* The cardiac or esophageal orifice of the stomach.

cardiac. *adj.* Pertaining to the heart.

cardiac end of stomach. The upper portion of the stomach above the entrance of the esophagus.

cardiophrenic angle. The angle between the margin of the heart and the diaphragm.

cardiospasm. *n.* Spasm of the lower end of the esophagus.

caries. *n.* Decay, as dental caries.

carpal bones. The small bones of the wrist, eight in number.

cartilage. *n.* The structure covering the ends of the long bones to form joints.

cartilaginous. *adj.* Composed of cartilage.

cascade stomach. A stomach with two sacs such that the upper sac fills first and contents are then cascaded into a lower sac.

caseous. *adj.* Cheesy, as the caseous consolidation of tuberculosis.

cassette. *n.* A holder for x-ray film, usually with double intensifying screens.

catarrh. *n.* Inflammation of a mucous membrane.

catheter. *n.* Small-caliber tube for insertion into the bladder or other cavity.

cathode. *n.* The negative terminal of an electrical apparatus, such as an x-ray tube.

cathode rays, cathode stream. The stream of negative electrons which flow from the cathode to the anode (target) of an x-ray tube when activated by a high-voltage electrical current.

cathode ray tube. A high-voltage discharge tube so constructed that the cathode stream is permitted to emerge from the tube.

cation. *n.* An ion which flows to the cathode of an electric cell or x-ray tube.

caudal. *adj.* Toward the lower end of the body.

cavity. *n.* An area of destruction of the normal tissues or organs; any hollow place within the body, such as the pleural cavity.

cc., c.c. Cubic centimeter(s).

CC. Chief complaint.

cecum. *n.* The pouchlike head of the large bowel proximal to its union with the small intestine.

-cele. *suffix.* Swelling.

cell (electric). *n.* A piece of apparatus assembled into a unit for the generation of an electric current by chemical action. Cells are connected in series, parallel, or multiple, to form electric batteries.

center of ossification. A center in an epiphysis from which bone begins to develop.

-centesis. *suffix.* Puncturing.

centigrade scale. A thermometric scale for the recording of temperature in which the freezing point is indicated at 0°C. and the boiling point at 100°C. Also called *Celsius scale.*

central. *adj.* Within the center of.

central fracture. A fracture through the center of a joint; for instance, central fracture of the acetabulum of the hip joint.

central ray. Principal ray.

cephalic. *adj.* Pertaining to the head.

cephalometer. *n.* An instrument for determination of the size of the fetal head and mother's pelvis in roentgen pelvimetry.

cerebellum. *n.* The smaller portion of the brain beneath the tentorium (fibrous partition), which is the seat of most regulatory mechanisms of the body.

cerebral. *adj.* Pertaining to the cerebrum of the brain.

cerebrospinal fluid. The fluid normally present in the ventricles of the brain and spinal canal.

cerebrum. *n.* The greater portion of the brain above the tentorium (fibrous partition), which has to do with all mental functions and activities.

cervical. *adj.* Pertaining to the neck or to the cervix of the uterus.

cervical spine. The portion of the spine contained in the neck.

cervical vertebrae. The vertebrae of the neck, seven in number.

cervico-. *prefix.* Pertaining to the neck or to the cervix of the uterus.

cervix of the uterus. The neck of the uterus.

characteristic radiation. The type of secondary radiation resulting when rays from an x-ray tube strike inorganic substances.

characteristic rays. Secondary rays produced when x-rays strike inorganic substances of greater atomic weight than aluminum.

Charcot's joint. A destruction process caused by the late effects of syphilis.

chemical fog. A blurred appearance of the radiograph produced by contaminated developer or other chemicals, not by light or x-rays.

chemotherapy. *n.* Treatment with chemical compounds (e.g., sulfonamides, arsphenamine) which inhibit the life processes of disease-causing organisms without injuring the patient's tissues.

chest. *n.* The upper portion of the trunk housing the heart and lungs, separated from the abdomen by the diaphragm.

choke coil. A piece of electrical apparatus consisting of a coil of wire wound about an iron core, introduced into an alternating current circuit, the purpose of which is to control the amount of current flowing, by means of the choking effect of various amounts of iron core inserted into the coil.

chole-. *prefix.* Pertaining to bile.

cholecyst-. *prefix.* Pertaining to the gallbladder.

cholecystitis. *n.* Inflammation of the gallbladder.

cholesteatoma. *n.* A mass of granulation tissue in a large bone cavity caused by chronic infection which forms cholesterin crystals.

chondritis. *n.* Inflammation of cartilage.

chondroma. *n.* A benign cartilaginous tumor.

choroid plexus. A plexus or network of blood vessels on the inner wall of the lateral ventricles of the brain.

Chr. Chronic.

-chromic. *suffix.* Colored.

chronic. *adj.* Having a protracted, prolonged course.

-cidal. *suffix.* Destructive.

circuit. *n.* A completed pathway of conducting materials for the flow of an electric current.

circum-. *prefix.* Around

clavicle. *n.* The collarbone, extending between its joint with the acromion process of the scapula laterally to its joint with the sternum near the midline.

claw hand. A clawlike deformity of the hand due to contraction of the extensor muscles.

cleft. *n.* A groove or separation.

clinoid processes. Small bony processes adjacent to the sella turcica in the skull.

cm. Centimeter(s).

CM. Costal margin.

CNS. Central nervous system.

coagulation. *n.* The congealing of a liquid; as, coagulation of the blood.

cocaine. *n.* A drug used to produce local anesthesia.

cocainization. *n.* Infiltration of a tissue with cocaine for local anesthesia.

coccus. *n.* A sphere-shaped microorganism.

coccyx. *n.* The tail bone at the end of the spine, usually composed of three or more segments, attached to the lower end of the sacrum.

cohesion. *n.* The clinging together of the particles of a substance.

colitis. *n.* Inflammation of the colon.

collapse. *v.* To fall together. *n.* The state of a patient when his faculties fail and he becomes unconscious.

Colles's fracture. Fracture of the lower end of the radius.

collision. *n.* The striking together of two material bodies.

colloidal solution. A solution in which electrically charged particles are held in suspension.

colon. *n.* The large bowel.

colostomy. *n.* An artificial opening into the colon.

colpo-. *prefix.* Pertaining to the vagina.

coma. *n.* A state of unconsciousness.

comminute. *adj.* Splintered, crushed.

commutator. *n.* A piece of electrical apparatus designed for reversing the flow of an electric current; the segmented contacts on the end of the shaft of a motor, or generator.

compensating filter. A filter of aluminum or plastic opaque material which is interposed between the x-ray tube and the patient so as to shield less dense areas, and thereby produce a more uniform quality in the radiograph.

complete fracture. A fracture which extends completely through the bone.

compound fracture. A fracture of a bone which penetrates the skin or communicates with the outside air.

compression cap. A rounded cap of radiotransparent material used for pressure in examination of the gastrointestinal tract.

compression fracture. A fracture in which the spongy portion of the bone is compressed.

condenser. *n.* A piece of electrical apparatus consisting of a number of metallic plates arranged parallel with each other, alternately connected to opposite charges but separated by insulating material, the purpose of which is to store up an electrical charge; a chamber in which gases are cooled.

conductivity. *n.* The property which permits the passage or flow of an electric current, or the conduction of heat.

condyle. *n.* A rounded projection on a bone which forms an articulation.

condyles of the femur. Two rounded prominences of bone at the lower end of the femur which form the joint with the knee.

cone. *n.* A metallic tubular extension which can be placed between the x-ray tube and the patient to limit the field of examination to that of the structures desired and to aid in the proper centering of the rays.

congenital. *adj.* Present at birth.

congestion. *n.* Stagnation of blood due to interference with normal circulation.

connective tissue. The cellular fibrous tissue which forms the network between the various structures of the body.

consolidation. *n.* Solidification of a porous structure, as consolidation of the lung.

constant-potential. An electric current having a constant direct voltage.

constriction. *n.* The narrowing of the lumen, or opening, of a tubular structure.

contra-. *prefix.* Against.

contract. *v.* To become shorter or smaller.

contrast. *n.* The difference in density between highlights and shadows.

convergence. *n.* The coming together of lines or rays; as convergence of radiation.

converter (rotary). *n.* A motor run by one type of electrical current which acts as a generator for another type of current motor-generator, thereby converting the current from one type to another, as D.C. to A.C. current.

convolutional atrophy. Atrophy of the bones of the skull, taking on the form of the convolutions of the brain, due to increase in intracranial pressure.

convolutional markings. The markings produced on the skull from pressure of the convolutions of the underlying brain.

Coolidge control. The choke coil used to control the heat of the filament of an x-ray tube.

Coolidge transformer. The small step-down transformer used on x-ray apparatus to furnish current for lighting the filament of the x-ray tube.

Coolidge tube (of universal type). The hot-cathode tube originally designed by William D. Coolidge having a solid tungsten target and an incandescent filament for the cathode, operating in a vacuum tube.

coracoid process of the scapula. The hooklike process projecting from the scapula for muscle attachments.

core. *n.* A piece of iron introduced into the center of a coil of wire to confine or concentrate the magnetic lines of force produced when activated by an electric current.

corona. *n.* The brushlike discharge of a high-voltage electric current which takes place from sharp points and angles in a high-tension circuit.

coronal plane. A plane parallel to the front of the body. Also *frontal plane.*

coronal suture. The suture of the skull running transversely across the front part of the head between the frontal and parietal bones.

coronary thrombosis. Occurrence of a clot in one of the coronary arteries of the heart.

coronoid fossa. The depression in the anterior surface of the lower end of the humerus into which the coronoid process of the ulna fits during flexion of the elbow.

coronoid process of the mandible. A beaklike projection on the upper anterior edge of the lower jawbone.

corpus. *n.* Body.

cortex. *n.* The outer gray matter of the brain.

cortical necrosis. Death or destruction of the cortical or functioning portion of an organ such as the kidney or brain.

cosmic rays. An extremely penetrating form of radiation of unknown origin, probably coming from outer space.

costal. *adj.* Pertaining to the ribs.

costal cartilages. The cartilages forming the anterior portions of the ribs, serving to attach them to the sternum.

costophrenic angle. The angle formed by the ribs and the diaphragm.

counter electromotive force. An electromotive force, or electric current, which is generated in the opposite direction in any electromagnetic coil activated by an alternating current. It is because of this counter electromotive force that a choke coil reduces the flow of an electric current.

cranial. *adj.* Pertaining to the skull.

cranium. *n.* The bony structure housing the brain.

crater. *n.* Hole or pit.

crest. *n.* A ridge of bone.

crinkle mark. *n.* A crescentic mark on the finished roentgenogram due to crinkling the film before exposure.

Crookes tube. A vacuum discharge tube used by Sir William Crookes in early experimental work.

cross-arm rectification. Mechanical rectification by means of cross arms for changing high-voltage alternating current to unidirectional current.

cuboid. *n.* One of the tarsal bones.

curettage, curettement. *n.* The operation of scraping with a curette, especially the interior of the uterus.

curie. *n.* The unit quantity of radioactive material. It is the quantity in which 37 billion disintegrations occur per second.

cuspids. *n.* The upper and lower teeth located between the lateral incisors and the first bicuspid tooth.

cutaneous. *adj.* Pertaining to the skin.

CVA. Cardiovascular accident.

cyanosis. *n.* Deficient oxygenation of the blood resulting in bluish appearance of the skin.

cycle of an alternating current. The time required for the charge at any place in the circuit starting with its maximum positive charge to alternate to its maximum negative charge and again return to maximum.

cyst. *n.* Any sac, especially an encapsulated collection of fluid, normal or otherwise.

cystitis. *n.* Inflammation of the urinary bladder.

cysto-. *prefix.* Pertaining to a bladder (any sac containing a liquid).

cystogram. *n.* A roentgenogram of the urinary bladder after distension with a medium of different density.

cystography. X-ray examination of the bladder after introduction of some substance of greater or lesser density than the normal tissues, such as opaque solution or air.

cystoscope. *n.* An instrument used for examination of the inside of the bladder, an electrically lighted tube with suitable lens system for introduction into the bladder, used for inspection of the bladder and catheterization of the ureters.

cystoscopic examination. Examination of the bladder through a cystoscope introduced into the bladder from without.

-cyte *or* **cyto-.** *suffix, prefix.* Pertaining to a biological cell.

D and C. Dilation and curettage.

decompensation. *n.* Failure to maintain normal function; as decompensation of the heart.

decubitus. *adj.* Lateral position, with the patient lying on his side.

defecation. *n.* Discharge of fecal material from the bowel.

degenerative. *adj.* Pertaining to the change of tissue to a lower or less functionally active form.

deglutition. *n.* Swallowing.

deliquescent. *adj.* Taking up moisture from the air.

deltoid muscle. A heavy muscle which overlies the shoulder.

density. *n.* The compactness of structure of a substance.

dental. *adj.* Pertaining to the teeth.

dental canal. A canal in the tooth structure.

depressed fracture. A fracture of a flat bone in which one edge of the bone is depressed below the other, as in a skull fracture.

derma- *or* **dermato-.** *prefix.* Pertaining to skin or covering.

dermatology. *n.* The field of medicine concerning the skin.

dermoid. *n.* A tumor containing elements of skin structure.

descending colon. The portion of the colon which descends from the splenic flexure along the left side of the abdomen.

dessicated. *v.p.p.* Dried; anhydrous in form (of chemicals without crystalline form).

detail. *n.* The clearness in the radiograph of the finer structures.

deuteron. *n.* The nucleus of a deuterium (heavy hydrogen) atom.

developer. *n.* The solution used for development of photographic and x-ray films, consisting of Elon and hydroquinone, as developing or reducing agents; sodium sulfite as a preservative; sodium carbonate, for alkalinization; potassium bromide, to prevent chemical fog.

di-. *prefix.* Twice or double.

dia-. *prefix.* Through.

diagnosis. 1. The process of determining what disease is present. 2. The conclusion reached by such a process.

diamagnetic. *n.* A non-magnetic substance, as silver, copper.

diaphragm. *n.* The flat muscular structure which forms a partition between the abdomen and chest.

diaphragmatic. *adj.* Pertaining to the diaphragm.

diaphyseal. *adj.* Pertaining to the diaphysis, or shaft side of an epiphyseal line.

diaphysis. *n.* The shaft of a long bone.

diastole. *n.* The resting stage of the heart during the heart beat cycle.

dielectric. *n.* An electric insulator.

difference of potential. Voltage.

differential diagnosis. 1. Strictly, a diagnosis made by closely comparing a case with several diseases that produce similar symptoms, so as to exclude as many as possible of the alternatives. 2. Loosely, a list of the diseases to be compared with a case in this manner.

diffraction. *n.* Interference in wave motion by interposition of a grating, causing breaking up of a light or x-ray beam into its component wave lengths.

diffraction angle. The angle between an incident ray and any resultant diffracted beam.

diffraction grating. A grating used to cause diffraction of light or x-rays.

digestion. *n.* The chemical process by which substances secreted by glands of the gastrointestinal tract act upon food and make it suitable for assimilation by the body.

dilatation. *n.* Enlargement.

dilated. *adj.* Distended.

diploetic. *adj.* Having the nature of the loose bony tissue found between the two tables of the cranial bone.

dis-. *prefix.* Apart.

discharge tube. Any vacuum tube in which a high-voltage electric current is discharged, as an x-ray tube.

discrete. *adj.* Well defined and clear cut in appearance, said of lesions which are not blended together.

disease entity. An abnormal condition producing a group of symptoms and signs related by their common cause. A disease entity is characterized by a specific syndrome.

dislocation. *n.* An abnormal relationship of structures; as the dislocation of the bones of a joint.

distal. *adj.* Farther away from the central portion of the body; as the distal fragment of a fracture, i.e., the fragment farthest away from the body.

distance. *n.* In radiography, the distance between the focal spot of the target and the film.

distention. *n.* Enlargement.

distortion. *n.* Variation from normal contour; misshaped appearance of the radiographic image.

divergence. *n.* A radiating outward from any point source of radiation.

diverticulitis. *n.* Multiple diverticula with evidence of associated inflammation.

diverticulosis. *n.* Presence of multiple diverticula in an organ, such as the large bowel, without evidence of inflammation.

diverticulum, -a. *n.* An outward pouching between the muscular coats of a hollow organ.

DOA. Dead on arrival.

dolichocephaly. *n.* Unusual length of the skull.

dorsal. *adj.* Of the back.

dorsal spine. The portion of the spine to which the ribs are attached connecting the cervical portion above with the lumbar portion below.

dorsal vertebrae. Vertebrae to which the ribs are attached, twelve in number.

dosage of x-radiation. A measure of the quantity of radiation delivered by an x-ray machine; either in time, at certain milliamperage, kilovoltage, and distance, or more accurately in "r" units.

dosage, tolerance. *n.* The amount of radiant energy which can be passed through normal living tissues without injurying them.

double-contrast enema. An enema given for x-ray examination in which barium sulfate is injected and expelled, and then the colon is inflated with air.

double exposure. Two superimposed exposures on the same film.

double-focus tube. A tube having two focal spots; one, small for greater detail; the other, broad to permit greater energy to be applied to the tube.

double ureter. Two distinct ureters on one side.

dr. Dram.

duodenal. *adj.* Pertaining to the duodenum.

duodenal bulb; duodenal cap. The triangular structure forming the first portion of the duodenum, seen on radiological examination.

duodenum. *n.* The first portion of the small intestine, into which the stomach empties.

dura mater. *n.* The outermost covering of the brain.

dwarfism. *n.* Small structure, below normal size.

DX. Diagnosis.

dynamo. *n.* A piece of electrical apparatus consisting of coils of wire revolving in a magnetic field, the purpose of which is to generate an electric current.

-dynia. *suffix.* Pain.
dys-, dis-. *prefix.* Difficult, abnormal, painful.

ec-. *prefix.* Out.
ecchymosis. *n.* Escaping of blood from the vessels into the surrounding tissues.
-ectasia. *suffix.* Dilatation.
ecto-. *prefix.* Outside, out, exterior.
-ectomy. *suffix.* Removal; excision.
ectopic. *adj.* Misplaced; improperly located.
EDC. Expected date of confinement.
edema. *n.* An abnormal outpouring of clear fluid into the connective tissues from the blood stream; dropsy.
edentulous. *adj.* Without teeth; having suffered loss of teeth.
EEG. Electroencephalogram.
EENT. Eyes, ears, nose, and throat.
effective voltage. The average voltage effective over the period of any phase of an electric current. It equals the root mean square of the variable voltage.
effective wave length. The wave length which would produce the same penetration as an average of the various wave lengths in a hetereogeneous bundle of rays.
effusion. *n.* Fluid filling a cavity of the body.
EKG. Electrocardiogram.
electric induction. The induction of an electric charge in a conductor of electricity when subjected to an electric field.
electrocardiogram. *n.* A record produced by an electrocardiograph.
electrocardiograph. *n.* An instrument for recording the electric current that originates in the heart muscle.
electrode. *n.* A terminal of a conductor of electricity, usually of metal or carbon.
electroencephalogram. *n.* A record produced by an electroencephalograph.
electroencephalograph. *n.* An instrument for recording the electric current that originates in the brain.
electromagnet. A magnet produced in a core of iron by an electric current passing through coils of wire wound around an iron core.
electromagnetic field. The magnetic field produced about an electromagnet.
electromagnetic induction, law of. Magnetic lines of force cut at right angles by a conductor of electricity induce in that conductor an electric current.
electromotive force (E.M.F.). The pressure of electrical charge; voltage.
electron. *n.* A negatively charged particle forming part of the atomic structure. In the atom it may revolve about the positively charged nucleus.
electron tube. A vacuum discharge tube of special design (Coolidge) so that the electron stream is projected outside the tube into the atmosphere. Also *Lenard tube.*

electroscope. An instrument for the detection of small charges of electricity. The most common type consists of a gold leaf attached to a metal rod suspended by an insulating support in a glass jar. Charging the rod causes the gold leaf to be repelled and to stand out at an angle.

electrostatic voltmeter. A highly specialized piece of electrical apparatus for the accurate measurement of high-voltage charges.

em-, en-. *prefix.* In.

embolism. *n.* The process by which a portion of a blood clot enters into the blood stream.

embolus. *n.* A fragment of a blood clot free in the circulatory system.

embryo. *n.* The earliest period of development of an organism.

embryology. *n.* The study of the development of the embryo.

E.M.F. Electromotive force.

-emia. *suffix.* Blood.

emissary veins. Vessels communicating between the circulation inside and that outside the cranial cavity.

emphysema. *n.* Overdistention of the tissues with air: pulmonary emphysema is overdistention of air sacs with air; subcutaneous emphysema is distention of subcutaneous tissues with air.

empirical. *adj.* Concerned with experience or experiment.

empyema. *n.* Pus in the pleural cavity.

emulsion. *n.* The chemical coating of a photographic plate or film, sensitive to radiation. It consists of the halides of silver (bromide, chloride, and iodide).

en-, em-. *prefix.* In.

encephalo-. *prefix.* Pertaining to the brain.

encephalocele. *n.* An artificial protrusion of the membranes of the brain.

encephalography. *n.* Roentgenographic examination of the skull after withdrawal of the spinal fluid and replacing it with air.

enchondroma. *n.* A benign tumor composed of cartilage.

encroachment. *n.* Invasion of one tissue by another.

endo-. *prefix.* Inside, within, interior.

endocarditis. *n.* Inflammation of the endocardium, the lining of the cavities of the heart.

endocrine glands. Ductless glands: the pituitary, thyroid, thymus, etc.

endocrine secretion. An internal secretion of a ductless gland.

endocrinology. The field of medicine concerning the endocrine glands.

endosteal. *adj.* Pertaining to the endosteum.

endosteum. *n.* The fibrous lining of the medullary cavity of the bones.

endothelial tissue. The tissue that lines the inner surfaces of the heart, arteries, veins, and other closed cavities of the body.

endothelioma. *n.* A new growth arising from endothelial tissue.

enema. *n.* Injection of fluid solution into the large bowel. In a barium enema, the solution is of a barium mixture. In a double contrast enema, air and a barium mixture are used for outlining the bowel.

energy. *n.* A physical property of matter transmitted from one body to another whenever one performs work on the other.

energy, potential. *n.* The possibility of doing work. A weight raised to a height possesses potential energy.

ensiform process. The small triangular bony segment forming the lower end of the sternum. Also *xiphoid process.*

entero-. *prefix.* Pertaining to the intestines.

epi-. *prefix.* Upon, among, over, in addition to.

epicondyles of the humerus. The prominent bony processes at the lower end of the humerus, just above the elbow joint.

epiglottis. *n.* A flat cartilaginous projection extending above the opening of the trachea to prevent entry of food while it is being swallowed.

epilepsy. *n.* A disease of the brain characterized by convulsive seizures and periods of unconsciousness.

epiphyseal separation. Abnormal separation of the epiphysis from the bone shaft; usually due to injury.

epiphysis. *n.* The structure at the end of a long bone from which the bone grows.

epiphysitis. *n.* Inflammation of an epiphysis.

epithelium. *n.* The layer of cells covering a surface, as the skin.

equilibrium. *n.* A state of balance between two forces.

erosion. *n.* Necrosis of the edge of a solid structure such as bone, caused by local infection or a wearing process.

erythro-. *prefix.* Red.

erythrocyte. *n.* A red blood cell.

esophagus. *n.* The muscular tube which conveys food from the pharynx to the stomach.

-esthesia. *suffix.* Sensation.

ether. *n.* A medium which theoretically pervades all space, serving as a means for transmission of radiations, such as, light, x-rays, and gamma rays; also, a fluid used for inhalation to produce general anesthesia.

ethmoid bone. *n.* The sievelike bone forming the roof of the nasal cavity, housing ethmoid cells.

ethmoid sinuses. *n.* The air cells in close proximity to the nasal cavity.

ethmoidal. *adj.* Pertaining to the ethmoid cells or sinuses.

etiology. 1. The study of causes, especially of disease. 2. Loosely, a cause or a causative agent.

eventration of the diaphragm. An unusually high position of the diaphragm.

eversion. *n.* Outward rotation.

Ewing's tumor. A malignant new growth of bone.

ex-. *prefix.* Out or away from.

excretion. *n.* The separation and throwing off of waste products of the body by glandular action or other means.

exo-. *prefix.* Outer.

exotosis. *n.* An outgrowth of bone.

expiration. *n.* Blowing air out; act of exhaling.

exposure. *n.* The subjection of a film to the effects of light or x-rays.

extension. *n.* Straightening out of a part.

extensor muscle. Muscles which by their contraction cause extension of a part.

external. *adj.* Outside.

extra-. *prefix.* Outside of.

extracapsular. *adj.* Outside the capsule, as an extracapsular fracture.

extravasation. *n.* The escaping of blood or other body fluids from their natural channels into the surrounding tissues.

extrinsic. *adj.* Having origin outside the structure or organ involved.

exudate. *n.* Material poured out from the blood vessels and tissues in response to damage from injury or disease.

F. Fahrenheit.

facet. *n.* A small smooth area on a bone, usually for articulation; as the articular facet of a vertebra.

facial. *adj.* Pertaining to the face.

Fahrenheit (F.) scale. A scale for the recording of temperatures. The freezing point is indicated at 32° F. and the boiling point at 212° F.

fallopian tubes. Parts of the female pelvic organs. They spring from the upper ends of the uterus and extend outward on either side.

falx cerebri. The vertical membrane dividing the two sides of the brain.

fat-free meal. A meal used to prevent emptying of the gallbladder.

fat meal. A meal containing fat used to empty the gallbladder in the gallbladder test.

FB. Foreign body.

fecalith. *n.* Small calcium deposit in the walls of the intestine.

feces. *n.* The waste product of food digestion in the intestines.

femur. *n.* The large bone of the thigh.

FFD. Focus-film distance.

FH. Family history.

fibroma. *n.* A benign tumor of fibrous tissue origin.

fibromyoma. *n.* A benign tumor usually of the uterus. Also *fibroid.*

fibrosis. *n.* The replacement of normal tissues with fibrous tissues.

fibula. *n.* The smaller of the two bones of the leg.

field magnet. A magnet used to produce a magnetic field for the rotation of another electromagnet in the function of a motor or dynamo.

film. *n.* A piece of celluloid coated with a photographic emulsion consisting of the halides of silver.

filter. *n.* A sheet of metal through which the rays go before striking the object to be examined or treated. The most common types of filter in use are of copper or aluminum.

fissure. *n.* A division of the lung.

fistula. *n.* A false tract into the tissues.

flaccid. *adj.* Without tone; flabby.

flap fracture. A fracture of the skull in which the fracture line produces a flaplike break.

flat. *adj.* Showing a lack of contrast between the highlights and shadows (of a radiograph).

flatus. *n.* Gas.

fl. dr. Fluidram(s).

flexion. *n.* Doubling up of a limb by contraction of muscles.

flexor muscle. A muscle which by contraction causes flexion of a part.

flexure. *n.* A bend, as splenic flexure of the colon.

fl. oz. Fluidounce(s).

fluorescence. *n.* The emission of light from crystals of certain substances, such as barium platinocyanide, calcium tungstate, which are acted upon by x-rays. It is this property which makes the fluoroscopic screen possible.

fluoroscope. *n.* A piece of x-ray apparatus consisting of an x-ray tube properly housed and mounted so that x-rays emanating from the tube will strike a sheet of cardboard covered with calcium tungstate or other suitable fluorescent material. The object to be examined is interposed between the tube and the screen, casting its shadow of varying densities on the screen.

fluoroscopic examination. One of the two general methods of x-ray examination, by use of the fluoroscope.

fluoroscopy. *n.* The process of x-ray examination which utilizes direct examination with a fluoroscopic screen in a darkened room.

focal spot, focal point (FS). The small spot on the target of an x-ray tube which receives the impact of the electron stream from the cathode, and from which x-rays are emitted in all directions.

focus-film distance (FFD). The distance from the focal spot of the x-ray tube to the film. Also *target-film distance, anode-film distance.*

fog. *n.* A hazy appearance of a radiograph due to exposure to light or x-rays or subjection to uncontrolled chemical action.

fontanelle. *n.* The soft spot in a young baby's head.

foramen. *n.* An opening in a bone for the transmission of vessels, nerves, and other structures.

foramen magnum. The large opening in the base of the skull which transmits the spinal cord.

forearm. *n.* The portion of the upper extremity between the elbow and the wrist.

fossa. *n.* A hollow depression in a bone.

fracture. *n.* A break in the continuity of a bone.

Freiberg's infraction. A disease of the metatarsal bones (osteochondritis deformans metatarso-juvenalis).

frequency. *n.* Periodic recurrence of wave motion, as in the wave motion of an electric current.

friction marks. Artifacts on films due to discharge of static electric charges which accumulate as a result of rubbing together of the films; also, abrasion marks from rubbing.

frilling. *n.* Separation of the emulsion from the celluloid coat at the margins of the film.

frontal. *adj.* Pertaining to the front portion of the body.

frontal bone. The flat bone which forms the forehead.

frontal plane. A plane which divides the body into ventral and dorsal parts. Also *coronal plane.*

frontal sinus. The accessory nasal sinus located in the frontal bone.

frontal view of the skull. A view taken with the frontal bone in contact with the film.

fronto-malar suture. The suture between the frontal and malar bones seen on the lateral sides of the orbits.

FS. Focal spot.

full-wave rectification. Rectification of the entire wave of an alternating current.

function. *n.* The work normally required of a part or structure; *v.* to carry on this work.

FUO. Fever of undetermined origin.

fused kidneys. An anomalous condition in which the kidneys are partially united.

gallbladder. *n.* The reservoir for bile.

galvanometer. *n.* A delicate electrical instrument for the measurement of extremely small electrical currents.

gamma rays. The wave motions in the ether spontaneously emitted from radium active deposit.

gangrene. *n.* Necrosis of tissue plus putrefaction.

gastric. *adj.* Pertaining to the stomach.

gastritis. *n.* Inflammation of the stomach.

gastro-. *prefix.* Pertaining to the stomach.

gastrocnemius. The heavy muscle forming the calf of the leg.

gastroenterostomy. *n.* The creation of an artificial opening between the stomach and intestines.

gastrointestinal. *adj.* Pertaining to the stomach and intestines.

GB. Gallbladder.

Geiger counter. An instrument that registers ionizing particles in the air, used in radiology principally for the detection of small quantities of radium which have been lost.

generator motor. *n.* A motor which turns a generator, often used where a current of one type is available and a current of another type is desired, as in the conversion of alternating to direct current.

-genesis. *suffix.* Regeneration, production.

geriatrics, gerontology. *n.* The field of medicine concerning conditions typical of aged people.

gero-, geronto-. *prefix.* Pertaining to old age or to the aged.

G.I. Gastrointestinal.

giant cell tumor. A specific type of tumor of bone.

glabella. *n.* The bony prominence on the forehead just above the root of the nose.

gladiolus. *n.* The second bony division of the sternum.

glenoid cavity. The cavity of the scapula forming the shoulder joint.

glenoid fossa. The depression for articulation with the jawbone.

glioma. *n.* A tumor of nerve-tissue origin.

glosso-. *prefix.* Pertaining to the tongue.

glottis. *n.* Upper opening of the air passage.

gluteus muscle. The muscle forming the prominence of the buttock.

Gm., gm. Gram(s).

gonad. *n.* A sex gland.

gonado-. *prefix.* Of an ovary or testicle.

gono-. *prefix.* Seed or semen, generation, offspring.

gonococcus. *n.* The microorganism producing gonorrhea.

gout. *n.* A metabolic disease especially affecting the great toe.

gr. Grain(s).

grain. *n.* The degree of coarseness of the surface of a screen or film due to the small crystals which make up the coating.

granulation. *n.* The formation in wounds of small, rounded, fleshy masses.

granuloma. *n.* A granulating mass of tissue, usually the response to some type of infection.

grating. *n.* A diffraction grating.

greater trochanter. A large prominence of bone on the outer side of the upper end of the femur.

greenstick fracture. An incomplete fracture with one side of the bone broken and the other side intact.

grid marks. The shadows cast by the Bucky diaphragm grid from faulty technique.

groove. *n.* A small linear depression in a bone.

grs. Grains.

gt(t). Drop(s).

gumma. *n.* A gummy tumor causing destruction of tissue, a feature of later or tertiary syphilis.

gyneco-, gyno-. *prefix.* Pertaining to the female.

gynecology. The field of medicine concerning conditions peculiar to women, especially diseases of the reproductive organs.

half-life. *n.* The unit of measure for the rate of decay of a radioactive substance. It is a period measured from any moment at which the amount of radiation from a given mass of the substance is known to the moment at which this amount has declined to just half its initial value. For any given radioactive element this period is the same, no matter when the measurement is begun. Also *half-decay period.*

half-value layer (HVL). The thickness of a given filter, such as aluminum or copper, which will reduce the ionizing effect of the primary x-ray beam to one-half of its value. In radiation therapy, it indicates the average penetration of a given beam of x-rays.

half-wave rectification. Electrical rectification of one-half of the sine wave in alternating current.

halides. *n.* Compounds of metals with the halogen elements, bromine, chlorine, and iodine. Fluorine is also a halogen element.

hardening solution. A solution of alum and acetic, or sulfuric acid, used to harden the emulsion on a film; usually combined with the hypo bath.

hardness of x-rays. The penetrating power of x-rays; the harder the rays, the greater is their penetration.

head of the femur. The rounded upper end of the femur for articulation with the acetabulum to form the hip joint.

head of the radius. The upper end of the bone which articulates with the lower end of humerus.

helix (of wire). A cylindrical coil made by many turns of wire.

hema-, hemato-, hemo-. *prefix.* Pertaining to blood.

hemangioma. An angioma.

hematogenous. *adj.* Having origin in blood.

hematology. The field of medicine concerning the blood and the blood-forming organs.

hematoma. *n.* Swelling of soft parts due to extravasation of blood.

hematuria. *n.* Blood in the urine.

hemi-. *prefix.* Half.

hemihypertrophy. *n.* Excessive growth of one half or one side of the body or of an organ.

hemoglobin. *n.* The coloring matter in the red blood cells.

hemophilia. *n.* A condition in which certain elements necessary for normal clotting are congenitally absent from the blood.

hemorrhagic. *adj.* Related to bleeding.

hepatic. *adj.* Pertaining to the liver.

hepatic flexure of colon. The place where the ascending colon turns under the liver to go transversely across the abdomen.

hepato-. *prefix.* Pertaining to the liver.

hereditary. *adj.* Passed along to a descendant from ancestors.

hernia. Rupture, e.g., protrusion of abdominal contents through a weak spot in the abdominal wall or the diaphragm.

herniotomy. 1. Cutting into a hernia. 2. Herniorrhapy, i.e., repairing a hernia.

hertzian waves. Electromagnetic waves of long wave length and frequency; radio waves.

heterogeneous radiation. Bundles of rays having varying wave lengths, such as the light rays which come from the sun or the x-rays which come from an x-ray tube.

high-frequency (current) oscillation. The reversing character of a high-voltage discharge from a condenser.

hilum, hilus. The root of the lung.

hip joint. *n.* The joint between the acetabulum of the innominate bone and the head of the femur.

Hodgkin's disease. A fatal disease characterized by enlargement of the lymph glands, especially those in the neck.

homogeneous. *adj.* Having similar uniform composition, as homogeneous radiation.

homogeneous radiation. Radiation in which the rays have the same wave length, such as the characteristic secondary radiation produced when x-rays strike metal.

hormone. A substance secreted by a ductless gland, regulating the functions of other organs.

horseshoe kidney. An anomalous condition in which the kidneys are fused across the midline in a horseshoe shape.

hot-cathode tube. Any x-ray tube utilizing a heated cathode for its source of electrons.

hourglass stomach. A stomach which is constricted in the middle with pouches above and below like an hourglass.

humerus. *n.* The long bone of the arm.

HVD. Hypertensive vascular disease.

HVL. Half-value layer.

hydro-. *prefix.* Pertaining to water or hydrogen.

hydrocephalus. *n.* Excessive collection of fluid in dilated ventricles of the brain.

hydronephrosis. *n.* Overdistention of the kidney pelvis with urine.

hyoid bone. A floating bone in the neck above the larynx which is suspended from the styloid processes of the temporal bones on either side.

hyper-. *prefix.* Exceeding some normal degree; overmuch; above.

hypermotility. *n.* Excessive movability.

hypernephroma. *n.* A tumor derived from suprarenal tissue of the gland or misplaced in the kidney.

hyperparathyroidism. *n.* A condition resulting from abnormal increase in secretion of the parathyroid glands.

hyperplastic. *adj.* Associated with an overgrowth of tissue.

hypertension. *n.* Higher blood pressure than normal.

hypertonic. *adj.* Having more than normal muscular tone.

hypertrophic. *adj.* Excessive growth of tissue.

hypertrophic arthritis. An inflammation of a joint associated with overgrowth of bone at the joint margin.

hypertrophy. *n.* Enlargement, or overgrowth, of a part of the body.

hypo (sodium thiosulfate). *n.* Bath for the fixing of films; this dissolves all the silver salts which remain unaffected by light or x-rays.

hypo-. *prefix.* Less than some normal degree; too little; beneath.

hypodermic. *n.* Injection beneath the skin by means of a syringe.

hypodermoclysis. *n.* Injection of saline solution under the skin to supply the body with fluid.

hypostatic. *adj.* Pertaining to or associated with settling of blood due to a feeble blood current.

hyposulfite of soda. Hypo.

hypotension. *n.* Low blood pressure.

hypotonic. *adj.* Having less than normal muscle tone.

hystero-. *prefix.* Pertaining to the uterus.

-iasis. *suffix.* Morbid condition.

-iatrist. *suffix.* Specialist.

-iatry. *suffix.* Field of medicine.

idio-. *prefix.* One's own.

idiopathic. *adj.* Of unknown origin.

ileocecal region. The region where the ileum joins the cecum.

ileum. *n.* The third portion of the small intestine.

ileus. *n.* Obstruction to the normal flow of intestinal contents. It may be either mechanical or paralytic.

ilium. *n.* The flaring portion of the hip bone.

IM. Intramuscular.

image. *n.* The impression made on an x-ray or photographic film by x-rays or light.

impacted. *adj.* Lodged firmly in position; one end driven into the other, as in impacted fracture.

impulse timer. An instrument used in radiography for fractional second exposures.

incomplete fracture. A fracture which does not extend completely through the bone.

induction coil. A piece of electrical apparatus consisting of two coils of wire. One, a primary coil, consists of a few turns of heavy wire wound about an iron core; the other, a secondary coil, consists of many turns of fine wire wound about (but insulated from) the primary coil. The apparatus is usually equipped with a make and break mechanism. The purpose of the apparatus is to induce a current of higher voltage in the secondary coil.

induction of an electric current. The production of an electric current in a coil or other body, by close proximity to another bearing a varying electrical current, as in an induction coil or transformer.

infarct. *n.* An area in which death of tissues has occurred from loss of blood supply due to obstruction of the nutrient artery.

infection. *n.* The invasion of body tissues by pathogenic organisms.

infective. *adj.* Produced by pathogenic microorganisms.

inferior. *adj.* Below.

infiltration. *n.* The permeation of a tissue by substances not normal to it.

inflammation. *n.* A natural reaction of the body to injury or irritation; the process by which blood cells and serum flow out from blood vessels into an infected or injured area and attempt to destroy the infection and repair the injury.

influenza. *n.* An infection of the respiratory tract due to influenza viruses.

infra-. *prefix.* Below.

infraclavicular. *adj.* Below the clavicle.

infrared. *adj.* Of longer wave length than red light.

inguinal region. *n.* The fold between the abdomen and the thigh.

inner malleolus. *n.* The projection of bone at the lower end of the tibia which forms the bony prominence on the inner side of the ankle joint.

innominate bones. The large irregular pelvic bones forming the pelvis.

inspiration. *n.* The drawing in of air; the act of inhaling.

inspissated. *adj.* Thickened by absorption of fluid content, as inspissated pus.

insulating transformer. A transformer having a similar number of turns of wire in the primary and secondary coils, which serves to insulate either side of the circuit from the ground.

insulation. *n.* Material (usually nonconducting) used to prevent the escape or flow of an electric current.

insulator. *n.* A nonconducting material used to confine or prevent the flow of an electric current.

integral timer. A timer connected in the circuit of an x-ray machine which adds up the periods of exposure into a total quantity of time.

intensifier. *n.* A chemical solution for the intensification of an image on a photographic film.

intensifying screen. A screen composed of fluorescent material placed in close contact with an x-ray film to intensify the action of x-rays in radiography.

intensity. *n.* Strength; concentration.

inter-. *prefix.* Between.

intercostal. *adj.* Between ribs.

intermittent. *adj.* Having a time interval between impulses.

internal. *adj.* Inside.

internal resistance. The electrical resistance which is present within a piece of apparatus, as the internal resistance of a battery.

interrupter. *n.* A mechanical or chemical device for the periodic make and break of an electric current, used chiefly with induction coils.

interrupterless transformer. A transformer which utilizes alternating current for its changes in a magnetic field and does not require an interrupter to vary the magnetic field.

interspace. *n.* The space between two structures, as between ribs.

interstitial. *adj.* Located in the interspaces of a tissue; between the cells.

interstitial fibrosis. Laying down of fibrous tissue in the interstitial tissues between the normal structures.

intertrochanteric fracture. A fracture extending between the trochanters of the upper end of the femur.

intervertebral disc. One of the cartilaginous discs between the vertebrae.

intestinal. *adj.* Pertaining to the intestines.

intra-. *prefix.* Within.

intraarticular. *adj.* Within a joint.

intracapsular. *adj.* Within the capsule of a joint.

intracranial. *adj.* Within the skull.

intraoral. *adj.* Within the mouth.

intraspinal. *adj.* Into the spinal canal.

intratracheal. *adj.* Within the trachea or windpipe.

intrauterine. *adj.* Within the uterus.

intravenous. *adj.* Into a vein.

intrinsic. *adj.* Having origin within the structure or organ involved.

intussusception. *n.* Pushing in of one segment of the bowel into another; telescoping of the bowel.

inverse square law. The law which is applied to all point source radiation: the intensity of illumination at any region is inversely proportional to the square of the distance from the source.

inversion. *n.* In photography, the reversal of an image occurring with a lens system; in roentgenology, the reversal of an image as seen by direct effect of rays of the retina of the eye; in anatomy, inward rotation.

involucrum. *n.* The periosteal new bone formed to replace the destroyed bone in osteomyelitis.

involuntary. *adj.* Uncontrolled by voluntary action.

iodized oil. Oil which contains iodine in combination, used as an injection to provide an opaque medium for the visualization of the bronchi, sinuses, and other passages.

ion. *n.* An electrically charged particle not attached to a molecule. An ion may bear either a negative or a positive charge.

ionization. *n.* The process (usually chemical or electrical) by which ions are released from a substance. This renders it a conductor of electricity.

irradiate. *v.t.* To subject a substance to radiation, as to irradiate milk.

irradiation. *n.* Subjection to the action of radiation: light, or x-rays.

irregular bone. *n.* Vertebra.

ischium. *n.* The lower portion of the pelvic bone which supports the body's weight in sitting.

iso-. *prefix.* The same or similar.

-itis. *suffix.* Inflammation of.

IV. Intravenous.

jejunum. *n.* The second portion of the small intestine, the portion which extends from the duodenum to the ileum.

junction. *n.* The point of joining or uniting.

keloid. *n.* Excessive scar tissue.

Kenetron tube. A valve tube for rectification of high-voltage current.

Kg. Kilogram(s).

kidney. *n.* The organ which separates urine from the blood stream.

Kienböck's disease. A disease of the carpal bones.

kilo-. *prefix.* One thousand, as kilogram—1000 grams, kilovolt—1000 volts.

KUB. Kidney, ureter, bladder.

Kümmell's disease. A disease of the spine usually appearing after an injury.

kymograph. *n.* A piece of x-ray apparatus used in recording the range of motion of various organs, especially the chambers of the heart throughout the cardiac cycle.

kymoscope. *n.* A piece of x-ray apparatus used in viewing films taken with the kymograph.

kyphosis. *n.* Curvature of the spine with convexity backward, producing hump-backed deformity.

labyrinth. *n.* Communicating cavities and canals making up the inner ear.

lacerated. *adj.* Cut or incised by a sharp instrument.

lacrimal duct. Tear duct.

lacrimal gland. Tear gland.

lag. *n.* In radiology, the continued radiation from an x-ray intensifying screen, after it is itself no longer subjected to radiation.

lambdoid suture. The suture between the parietal bones and the occiput of the skull.

laminagraph. *n.* A piece of x-ray apparatus used for roentgenographing a thin layer of tissue at any depth in the body without interference with the intervening structures. Also *tomograph*.

laminated. *adj.* Having many thin layers, similar in structure to an onion.

laparo-. *prefix.* Pertaining to the flank or abdomen.

laryngology. *n.* The field of medicine concerning the larynx (voice box) and associated structures.

larynx. *n.* The voice box.

latent image. The image produced on a photographic or x-ray film by the action of light or x-rays before development.

lateral. *adj.* Refers to that portion of a structure or part which is the greatest distance from the midline.

lateral sinus. A venous channel running inside the skull near the mastoid.

lateral ventricle. A large space in the brain containing cerebrospinal fluid.

latitude. *n.* The range of exposure of an x-ray film permissible for a good diagnostic result.

law of conservation of energy. Energy can be changed in form but can be neither created nor destroyed.

law of electrical charges. Unlike charges attract; like charges repel.

law of inverse squares for all point source radiation. The intensity of illumination is inversely proportional to the square of the distance from the source.

law of magnetic induction. Magnetic lines of force, cut at right angles by a conductor of electricity, induce in that conductor an electric current.

law of magnetism. Unlike magnetic poles attract; like poles repel.

Law's position. Positions for radiographic examination of the mastoids.

leg. *n.* The portion of the lower extremity between the knee and ankle.

Legg-Calvé-Perthes disease. A disease of the epiphysis for the head of the femur.

Lenard tube. An electron tube.

leontiasis ossea. A disease of the facial bones giving the patient a lionlike expression.

leprosy. *n.* A wasting disease affecting especially the skin and extremities.

lesion. *n.* Any local pathological condition.

lesser trochanter. The smaller of two bony prominences on the upper end of the femur for the attachment of muscles.

leuco-, leuko-. *prefix.* White, colorless.

leucocyte. *n.* A white blood cell.

leukemia. *n.* A fatal disease involving the white blood corpuscles and blood-forming organs.

leukocytosis. *n.* Increase in the proportion of white blood cells in the blood.

leukopenia. *n.* Diminution in the white blood cell content of the blood.

ligament. *n.* A strong band of fibrous tissue usually found at a joint.

ligamentum teres. The so-called "round ligament" of the hip joint.

light trap. A labyrinth so arranged that light cannot enter. It is used for entrance to a dark room.

linear fracture. A fracture like a line.

line focus. A linear focal spot on the target of an x-ray tube.

lines of force. Imaginary lines along which magnetic force acts. They can be demonstrated by sprinkling iron filings on a piece of paper and placing it in the magnetic field to be investigated.

linguo-. *prefix.* Pertaining to the tongue.

linitis plastica. A disease of the stomach characterized by marked thickening of the stomach wall; leather-bottle stomach.

lipiodol. *n.* An opaque oil used for injection into body cavities for the purpose of x-ray examination.

liter. A measure of volume in the metric system; 1,000 cc.

-lithiasis. *suffix.* Stone.

liver. *n.* A large abdominal organ occupying the right upper quadrant of the abdomen, lying immediately beneath the diaphragm; it secretes bile.

LLQ. Left lower quadrant.

lobar. *adj.* Pertaining to a lobe of the lung.

lobe. *n.* A division of the lung.

localization of foreign bodies. The accurate measurement of the location of foreign bodies with relationship to the surface and to adjacent structures.

localized. Confined to a restricted position.

lodestone. *n.* A piece of natural magnetic iron ore.

-logy. *suffix.* Study or treatise.

long bone. *n.* A bone of the extremities having a shaft and articular ends.

longitudinal fracture. A fracture extending along the long axis of a bone.

lordosis. *n.* Curvature of the spine with convexity forward.

lues. *n.* Syphilis.

lumbar spine. The portion of the spine below the thorax which forms the back support of the abdominal cavity and is attached to the sacrum below.

lumbar vertebrae. The vertebrae below the dorsal spine, five in number.

lumen. *n.* The channel of a tubular structure, as the lumen of a hypodermic needle.

luminescence. *n.* Radiation coming from a substance as a result of previous action of some form of energy in the substance—for instance, the luminescence of phosphorus after exposure to sunlight.

lungs. *n. pl.* The organs of respiration in which oxygen of the air is absorbed by the circulating blood.

LUQ. Left upper quadrant.

luxation. *n.* Abnormal slipping of one structure on another at a joint or place of natural division.

lymph. *n.* The all-pervading fluid in which the tissues are bathed. It offers a medium for exchange between the blood and the tissue cells.

lymphatic leukemia. A fatal blood disease characterized by enlargement of the lymph glands.

lymphatics. *n.* The lymph vessels and glands which collect the lymph from the tissues.

lymph glands. Glands which serve as filters for lymph collected in the peripheral tissues on its way to the general circulation.

lymph node. A lymph gland.

lymphoblastoma. *n.* A tumor composed of lymph cells.

lymphosarcoma. *n.* A malignant tumor of the lymph gland structure.

Lysholm grid. A stationary grid of fine lead strips which is used like a Potter-Bucky diaphragm.

-lysis. *suffix.* Dissolution.

M. Meter(s).

M^2. Square meter(s).

macro-. *prefix.* Large.

macrocephaly. *n.* Excessive size of the skull.

macroscopic. *adj.* Of a size big enough to be seen with the unaided eye, without use of a microscope.

magnet (permanent). *n.* A piece of iron possessing a certain force which causes it to attract other particles of iron, and thereby obey the other laws of magnetism.

magnetic field. The field of magnetic force surrounding a magnet.

magnetic induction. The induction of magnetism in a magnetic substance placed within a magnetic field.

magnetic pole. The end of a magnet. That pole which when free to oscillate points towards the earth's magnetic north pole is called the north-seeking or north pole; the end which points south is called the south pole.

make contact. To establish metallic contact between two conductors of electricity.

mal-. *prefix.* Bad, as malfunction, i.e., improper function.

-malacia. *suffix.* Softening.

malar bone. One of the bones of the face producing the prominence of the cheek.

malignant. *adj.* 1. Virulent, i.e., dangerous to life. 2. Pertaining to a tumor which tends to invade adjacent tissues and to spread to distant parts of the body.

malleolus. *n.* *See* inner malleolus *and* outer malleolus.

mammary gland. The breast.

mammography. *n.* Roentgenographic examination of the breasts.

mandible. *n.* The lower jawbone.

mandibular. *adj.* Pertaining to the mandible, or lower jaw.

mandibular canal. The canal in the mandible for the inferior alveolar vessels and nerve.

manubrium. *n.* The upper bony segment of the sternum.

march-foot. *n.* A disease of the metatarsal bones, produced by trauma from continued standing on the feet.

marginal ulcer. Ulcer occurring at the margin of a gastroenterostomy opening.

Marie-Strümpell disease. A disease of the spine resulting in complete bony ankylosis.

marrow. *n.* The soft material filling the cavities of bones.

masks. *n. pl.* Lead shields for shielding the field of examination so that further x-ray exposure may be utilized to blacken the surrounding field.

masseter. The strong muscle of the jaw which aids in mastication.

massive idiopathic atelectasis. A condition in which the lungs, previously well aerated, suddenly, without apparent cause, lose their air content and become atelectatic.

mast-., masto-. *prefix.* Breast.

mastication. *n.* Chewing and mixing of food.

mastoid. *n.* The bony process behind the ear.

mastoiditis. *n.* Inflammation of the mastoid cells.

mastoid suture. The sutures of the skull behind the mastoid process.

maxilla. *n.* The upper jaw bone.

maxillary. *adj.* Pertaining to the upper jaw.

maxillary antrum. One of the paranasal air sinuses located in the maxillary bones and draining into the nose.

maxillary sinus. One of the accessory nasal sinuses located in the maxillary bone.

Mayer's position. A position for radiographic examination of the petrous portion of the temporal bone.

mcg. Microgram(s).

mcl. Microliter(s).

meatus. *n.* Opening at the end of a canal; as the external auditory meatus.

mechanical ileus. Obstruction of the bowel from some mechanical obstacle.

medi-, medio-. *prefix.* Middle, halfway.

medial. *adj.* Near the midline.

mediastinum. *n.* The middle compartment of the chest containing the trachea, esophagus, heart, and great vessels.

medullary canal, medullary cavity. The inner hollow portion of a long bone containing the marrow.

megalo-. *prefix.* Large or great.

membrane. *n.* A thin layer of tissue covering a surface.

meningeal arteries. The arteries running in the meningeal covering of the brain.

meninges. *n. pl.* The membrane lining the spinal canal and brain.

meningioma. *n.* A tumor of the meningeal covering of the brain and spinal cord.

meningocele. *n.* An artificial outpouching of the meningeal membrane.

meno-. *prefix.* Menses or menstruation.

mental. *adj.* Referring to the chin.

mental foramen, foramen mentale. The opening in the mandible for the emergence of the dental nerve from its canal.

mesentery. *n.* The fold by which the intestines are attached to the posterior wall of the abdominal cavity.

meso-. *prefix.* Referring to the middle or the part between.

meta-. *prefix.* After; changing.

metabolic. *adj.* Pertaining to the building up and the breaking down of living material within the cell.

metacarpal bones. The short bones of the hand between wrist and fingers.

metastasis. Spreading of cancer to new sites of growth.

metatarsal bones. The short bones of the foot between the tarsal bones and the phalanges.

meter. *n.* An instrument used for measurement; a measure of length, 39.37 inches, abbreviated M.

-metrium. *suffix.* Uterus.

metro-, metra-. *prefix.* Uterus.

mg. Milligram(s).

MI. Mitral-valve insufficiency.

micro-. *prefix.* Small.

microcephaly. *n.* Abnormal smallness of the skull.

micrometer. *n.* An instrument for extremely accurate fine measurements.

micron. *n.* An extremely small unit of length, one-millionth of a meter, designated by the symbol μ.

microscopic. *adj.* So fine in structure that a microscope is required to see it.

micturition. *n.* Act of urination; emptying of the urinary bladder.

milk of calcium bile. A condition in which the bile in the gallbladder is filled with excess of calcium salts causing it to be opaque to x-rays in its natural state.

milliammeter, milliampere meter. *n.* A meter which measures milliamperage of current.

milliampere. *n.* One one-thousandth of an ampere.

minimal. *adj.* The smallest amount recognizable.

miscarriage. *n.* The premature expulsion of a viable fetus from the uterus.

ml. Milliliter(s).

mobility. *n.* The degree of movability of a structure, or organ; for example, the mobility of the stomach would be the degree by which it could be moved about by the radiologist in palpating the abdomen.

molar. *n.* One of the 12 large posterior teeth, 3 on each side of the upper and lower jaws.

molecular. *n.* An extremely small particle of matter, composed of atoms.

mon(o)-. *prefix.* Alone or one.

monochromatic. *adj.* Having a single wave length (of light rays or x-rays).

morphine. *n.* A drug used to allay pain.

motility. *n.* Power to move, as the peristaltic action of an organ.

motor. *n.* *See* generator motor *and* synchronous motor.

motor meal. A meal given with barium sulfate in gastrointestinal examination to investigate the motility of this tract.

MS. Mitral, stenosis.

mucosal. *adj.* Pertaining to a mucous membrane.

mucous colitis. An affection of the colon with secretion of large amounts of mucus.

mucous membrane. Any membrane or lining of a cavity of the body which secretes mucus.

mucus. *n.* The mucilagenous secretion from a mucous membrane.

multiphase. *adj.* Having many phases.

multiple fracture. More than one fracture.

myco-. *prefix.* Fungus, mold.

myelo-. *prefix.* Bone marrow or spinal cord.

myeloma. *n.* A tumor of the bone marrow.

myo-. *prefix.* Muscle.

myocarditis. *n.* Inflammation of the heart muscle.

myocardium. *n.* Heart muscle.

myositis ossificans. Calcium deposit in the muscles.

nasal. *adj.* Pertaining to the nose.

nasal bone. A bone of the nose.

nasal septum. The partition between the two sides of the nose.

nasal sinuses. The air spaces in the bone adjacent to the nose.

nausea. *n.* The sensation of a desire to vomit.

navicular. *adj.* Boat-shaped, scaphoid. *n.* A small bone of the wrist.

neck of a bone. A constricted portion beneath a head of a bone, as the neck of the humerus or femur.

necrosis. *n.* Death of tissue.

negative. *adj.* Having reversed light values, the lightest objects registering in the darkest tones, as in developed photographic film.

negative charge. An unstable condition of the atomic structure in which electrons are increased beyond the normal number.

negative pressure. Less than atmospheric pressure.

neoplasm. *n.* New growth; tumor.

nephritis. *n.* Inflammation of the kidney.

nephro-. *prefix.* Kidney.

nephroptosis. *n.* Dropping or descent of a kidney from its normal location.

neuritis. *n.* Inflammation of a nerve.

neuro-. *prefix.* Nerve.

neurogenic. *adj.* Pertaining to or having nerve origin.

neurology. The field of medicine concerning the brain, the spinal cord, and the peripheral nerves.

neurosis. *n.* A functional disorder of the nervous system.

neurotrophic. *adj.* Pertaining to the nerves which have to do with nutrition.

neutron. *n.* An electrically neutral particle of about the mass of a nucleus of a hydrogen atom.

nodular. *adj.* Having a bumpy consistence; composed of nodules.

nonossifying. *adj.* Showing no tendency to form bone.

non-rotation-of the colon. Failure of the colon to rotate into its normal position during embryological development.

nucleus (in physics). *n.* The central positively charged portion of the atom which is supposed to contain the mass of the atom, about which the electrons revolve.

nucleus pulposus. A semielastic body located between the vertebrae, acting as a hydraulic shock-absorber of the spine.

nutrient. *adj.* Supplying nourishment, or promoting growth.

nutrient artery. An artery which furnishes nourishment to a tissue.

ob. Obstetrics.

obese. *adj.* Very fat.

oblique fracture. A fracture extending obliquely through a bone.

obliterate. *v.t.* To remove completely.

obstetrics. *n.* The field of medicine concerning care of pregnancy (normal or abnormal), including delivery of babies and aftercare.

obstruction. *n.* An interference with the natural flow; the condition interfering with normal flow.

obstructive emphysema. Overdistention of the air sacs with air from partial obstruction of a bronchus.

obturator foramen. The oval opening in the lower portion of the pelvis near the hip joint.

occipital view of the skull. A view taken with the occiput in contact with the film.

occipito-. *prefix.* The back of head.

occiput. *n.* The flat bone which forms the back of the head.

occlusal film. Film placed between the occlusal surfaces of the teeth.

occlusion. *n.* Closure of a passageway or cavity.

odontoid. *adj.* Toothlike.

odontoid process. The toothlike projection of the second cervical vertebra where it articulates with the first cervical vertebra.

-odynia. *suffix.* Pain.

ohm. *n.* The unit of electrical resistance.

Ohm's law. $\text{Amperes} = \frac{\text{volts}}{\text{ohms}}$.

olecranon fossa. The depression on the posterior surface of the lower end of the humerus into which the olecranon process fits during extension of the elbow.

olecranon process. The heavy hooklike projection of bone forming the upper end of the ulna, which articulates with the lower end of the humerus.

oligo-. *prefix.* Little or few.

-ology. *suffix.* Knowledge or science (of).

-oma. *suffix.* Tumor or neoplasm.

omentum. *n.* Folds of the peritoneum connecting the stomach and transverse colon, hanging down in front of the intestines like an apron.

opacity. *n.* Imperviousness to light.

opaque. *adj.* Impenetrable by light.

opaque plastic. A light-absorbing material used as a compensating filter in radiographing structures of varying density.

opthalmo-. *prefix.* Eye.

ophthalmology. The field of medicine concerning the eyes.

optic. *adj.* Pertaining to the eye or vision.

optic canal. The canal for the passage of the optic nerve.

oral. *adj.* Pertaining to the mouth.

oral cavity. Mouth.

orbit. *n.* The path described by a body in its revolution about another, as the orbits of the earth and other planets revolving about the sun, or the orbit of an electron revolving about the nucleus of an atom; the bony cavity of the eye.

orchid-, orchi-. *prefix.* Testes.

organic lesion. A pathological condition pertaining to a part of the body having a special function.

orifice. *n.* Opening.

ortho-. *prefix.* Straight; of a normal degree, as orthotonic.

orthodiagraphic. *adj.* Mapping out an organ in its natural size.

orthopedics. *n.* The field of medicine concerning bones, joints, tendons, and muscles.

os calcis. The heel bone.

oscillograph. *n.* An instrument which traces a curve representing the characteristic behavior of an electric current in respect of time.

Osgood-Schlatter disease. A disease of the epiphysis for the tubercle of the tibia which results in its separation from the shaft.

-osis. *suffix.* Disease or morbid process, abnormal condition; also any production or increase.

osseous system. Bony skeleton.

osseous tissue. Bony tissue.

ossicles of the ear. Three small bones in the inner ear which transmit the vibrations in the air to the auditory apparatus.

ossification. *n.* Changing into bone.

ossifying. *adj.* Forming bone.

osteitis. *n.* Inflammation of a bone.

osteitis deformans. A chronic disease of the bones characterized especially by enlargement and thickening of the skull. Also *Paget's disease.*

osteitis fibrosa cystica. A cystic degeneration of bone.

osteo-. *prefix.* Bone.

osteoarthritis. *n.* A type of arthritis.

osteoblastic. *adj.* Bone-forming.

osteochondritis. *n.* An inflammatory process of the bone and cartilage at their point of attachment.

osteochondritis deformans metatarso-juvenalis. Freiberg's infraction.

osteochondritis dissecans. A disease of bone involving the articular cortex.

osteochondroma. *n.* A benign bone tumor.

osteoclastic. *adj.* Bone-destroying.

osteogenesis imperfecta. Imperfect formation of bone during bodily development.

osteogenic sarcoma. A malignant tumor arising from the bone.

osteoma. *n.* A benign bone tumor.

osteomalacia. *n.* Wasting disease of bone. **osteomalacic,** *adj.*

osteomyelitis. *n.* Infection involving the medullary portion of a bone.

osteopetrosis. *n.* Marble bones.

osteoplastic. *adj.* Forming new bone.

oto-. *prefix.* Ear.

otology. The field of medicine concerning the ears.

-otomy. *suffix.* Cutting.

outer malleolus. *n.* The lower end of the fibula forming the bony prominence on the outer side of the ankle joint.

ovaries. *n.* The female sex glands.

overdevelopment. *n.* Retention of a film in developing solution beyond the time of normal development.

overexposure. *n.* Too great exposure of an x-ray film to x-rays.

overpenetration. *n.* Too great penetration (kilovoltage) used in radiography.

oxycephaly. *n.* Abnormal height of the skull (tower skull).

P.A. Posterior anterior, from back to front.

Paget's disease. Osteitis deformans.

palate bone. The bone forming the hard palate.
palliative. *adj.* Affording relief, but not cure.
palmar. *adj.* Referring to the palm of the hand.
pan-. *prefix.* All.
panchromatic. *adj.* Sensitive to all colors of the light spectrum.
pancreas. *n.* A glandular organ located posterior to the stomach, the secretion from which aids in digestion of sugars.
para-. *prefix.* Beside, adjacent to; amiss.
paracentesis. *n.* Insertion of a hollow needle into a cavity for the purpose of withdrawal of fluid.
parallax. *n.* A method for the localization of a foreign body based upon the principle of relative change in relationship of a foreign body with respect to an object of known depth on displacement of the source of x-rays.
paralysis. *n.* Loss of nerve control of the muscles.
paralytic ileus. Obstruction to the normal flow of intestinal material due to paralysis of the muscular coat of the bowel.
parathyroid glands. A number of small glands the size of peas located in the neck behind the thyroid gland. They have to do with calcium metabolism.
parenchyma. *n.* The outer functioning portion of the lung containing the air sacs.
parietal. *adj.* At the outer edge, in contradistinction to *visceral,* as the parietal pleura lines the chest cavity; the visceral pleura covers the lung.
parietal bone. A large flat bone forming the side of the cranium.
parotid gland. One of the salivary glands situated in the soft tissues just in front of either ear, emptying its secretion into the mouth.
pars media of the stomach. Mid-portion of stomach.
-partum. *suffix.* Delivery, childbirth.
passive pulmonary congestion. Stagnation of blood in the lung from heart failure.
patella. *n.* The kneecap.
-pathic. *suffix.* Diseased.
patho-. *prefix.* Disease.
pathology. The study of the manifestations of disease in tissues and organs.
-pathy. *suffix.* Abnormality, disease.
p.c. After meals (post cibum).
P.E. Photographic effect of x-rays on an x-ray film; physical examination.
peak kilovoltage. The highest kilovoltage attained at any time in an electrical cycle.
pectoral muscles. The large muscles located in the anterior portion of the chest.
pediatrics. *n.* The field of medicine concerning conditions that are most common among children.
Pellegrini-Stieda disease. Calcification of the collateral ligament of the knee.

pelvicephalometer. *n.* An instrument for measurement of the fetal head and outlet of the mother's pelvis to determine relative size.

pelvic organs. The organs contained in the pelvis.

pelvimetry. *n.* Roentgenographic measurement of size of the bony pelvis.

pelvis. *n.* The bony ring formed by the innominate bones on either side and the sacrum behind, which serves as support for the pelvic and abdominal structures; (renal) the funnel-shaped structure which collects the urine from the calyces of the kidney and conveys it to the ureter.

penetration. *n.* The ability of radiation to extend down into and go through substances, as the penetration of x-rays.

peptic. Of esophagus, stomach, or duodenum.

perforating. *adj.* Breaking through.

peri- *prefix.* Around, as *periosteum,* around the bone.

peribronchial markings. The linear markings seen in a film of the lungs due to branching of the bronchi and their accompanying structures.

pericarditis. *n.* Inflammation of the pericardium.

pericardium. *n.* The membrane covering the heart and lining the pericardial cavity.

periesophageal. *adj.* Situated around the esophagus.

perinephritic. *adj.* Around the kidney.

perineum. *n.* The region between the upper portion of the thighs extending from the pubic arch to the coccyx.

periosteal sarcoma. A malignant tumor arising from the periosteum.

periosteum. *n.* The fibrous covering of a bone.

periostitis. *n.* Inflammation of the covering of a bone.

peripheral. *adj.* At the outer edge of.

perisinus abscess. *n.* A localized collection of pus around a venous sinus of the skull.

peristalsis. *n.* Wavelike contraction of the gastrointestinal tract by which its contents are moved forward.

peristaltic. *adj.* Pertaining to peristalsis, the movement of the alimentary canal.

peritoneum. *n.* The thin, smooth membrane lining the interior of the abdominal wall and covering the abdominal organs.

peritonitis. *n.* Inflammation of peritoneum.

permanent magnet. A piece of iron which retains its magnetism and does not depend for its magnetic properties on the flow of an electric current.

Perthes' disease. A bone disease affecting the epiphysis for the head of the femur.

petrous bone. The dense pyramidal process of the temporal bone which houses the auditory canal.

PH. Past history.

phago-. *prefix.* Eating; devouring.

phalanges. *n.* The bones of the fingers or toes.

phantom. *n.* Model of a body part.

pharynx. *n.* The portion of the throat connecting the mouth to the esophagus.

phase. *n.* The period of progress of an electrical vibration of an electric current cycle.

phlebo-. *prefix.* Vein.

phleboliths. *n. pl.* Small rounded calcium deposits in the walls of veins.

-phobia. *suffix.* Morbid fear.

photo-. *prefix.* Light.

photographic effect. (P.E.) The effect of light, or x-rays, on a photographic emulsion; in radiography,

$$\text{P.E.} = \frac{\text{milliamperes} \times \text{time of exposure} \times \text{Kv}^2}{(\text{target to film distance})^2}$$

photographic emulsion. The emulsion of the halides of silver, which forms the sensitive coating on a photographic or x-ray film.

photon. *n.* A particle of an atom broken off by impact of radiation, such as x-rays.

phrenic. *adj.* Pertaining to the diaphragm, as phrenic nerve.

phrenicectomy. *n.* Resection or removal of the phrenic nerve.

phrenic nerve. The nerve of respiration which supplies the diaphragm.

phrenicotomy. *n.* Cutting of the phrenic nerve.

physics. *n.* The science which deals with matter and energy in their relationships to each other, but not involving change of one substance into another.

physiological effect. An effect on living tissues.

PI. Present illness.

pia mater. The innermost covering of the brain.

pineal body, pineal gland. A small ductless gland which is present in the brain and has to do with growth.

pinhole photography. Photography using a pinhole in an opaque diaphragm as the "focusing" method; used both in photography and radiography.

pinhole radiograph. A radiograph taken through a pinhole in a lead diaphragm which results in an inverted image of the target, acting in the same way as a pinhole camera in photography. It is used to determine the actual size of the focal spot of a target and to indicate all points from which x-rays emanate.

pituitary fossa. A bony formation at the base of the skull which houses the pituitary gland; the sella turcica.

pituitary gland. A small glandular structure about the size of a pea which hangs down from the under surface of the brain into the pituitary fossa; one of the ductless endocrine glands.

placenta. *n.* The organ by which the fetus is attached to the mother's uterus through the umbilical cord.

-plastic. *suffix.* Formed.

plastic exudate. A soft pliable exudate thrown out around the fractured ends of bone.

pleura. *n.* One of the two thin, smooth membranes lining the interior of the chest and covering the surface of the lungs.

pleural. *adj.* Pertaining to the pleura.

pleural cavity. The cavity within the thorax containing the lung.

pleural effusion. Fluid filling the membranous sac covering the lung and lining the chest.

pleurisy. *n.* A disease marked by inflammation of the pleura.

plexus. *n.* A network, as a plexus of nerves.

PM. Postmortem.

pneo-. *prefix.* Breathing, breath.

pneumo-. *prefix.* Air-containing.

pneumococcus. *n.* The microorganism producing pneumonia.

pneumoconiosis. *n.* A disease of the lungs caused by prolonged inhalation of fine dust particles; the term is all inclusive and refers to injury from dust of any source.

pneumocystogram. *n.* X-ray examination of the urinary bladder after removal of urine and replacement with gas or air.

pneumocystography. *n.* Radiography of the bladder after filling the bladder with air.

pneumonia. *n.* An acute infectious disease of the lungs.

pneumoperitoneum. *n.* Air in the peritoneal (abdominal) cavity; used as an aid in examination of the abdominal organs.

pneumothorax. *n.* Air in the thoracic (chest) cavity.

podo-. *prefix.* Foot.

polarity. *n.* The negative or positive electric charge of a body or terminal.

polarity indicator. An instrument on an x-ray machine to indicate the phase of the current under which the machine is operating.

pole of a magnet. The end having affinity for the north or south magnetic poles of the earth.

poly-. *prefix.* Many.

polyarthritis. *n.* Arthritis of many joints.

polyarticular. *adj.* Involving many joints.

polycystic kidney. A congenital condition in which there are many cysts throughout the kidney substance.

polymorphism. *n.* The property which permits a substance to exist in more than one form, particularly with regard to crystalline structure; for example, sulfur exists in a crystalline and an amorphous form.

polyphase. *n.* An electric current having many phases.

polypi. *n. pl.* Small stemmed growths.

polyposis. *n.* The development of multiple small stemmed growths.

popliteal space. The space behind the knee.

position (standard for radiography). *n.* One of a set of positions generally accepted by radiologists as most satisfactory for radiographic examination.

positive charge. An atom or group of atoms in which, by some chemical change, the normal number of electrons are removed from the atom permitting the positive charge of the nucleus to predominate.

positron. *n.* A positively charged particle having the mass and equivalent charge of an electron.

post-. *prefix.* After.

posterior. *adj.* Of or at the back of a structure or part.

potassium ferricyanide. Red prussiate of potash.

potential. *n.* Pressure of electricity; voltage.

Potter-Bucky diaphragm. A piece of radiographic apparatus consisting of a grid of parallel strips of lead, the purpose of which is to reduce the effects of scattered radiation. Also *Bucky diaphragm.*

Pott's fracture. Fracture of the lower end of the fibula.

pre-. *prefix.* Before.

pregnancy. *n.* The condition of the female mammal when with child.

pressure atrophy. Atrophy of bony structure from pressure of an abnormal soft structure, such as a tumor.

primary circuit, primary winding. The circuit by which a current is introduced into an induction coil or transformer.

principal ray. The ray coming from the target of an x-ray tube perpendicular to its long axis. Principal rays show the least divergence and therefore produce the least distortion in roentgenography. Also *central ray.*

p.r.n. Whenever necessary.

process. *n.* (Of bone) a pronounced projection of the bony structure, as the transverse processes of vertebrae.

procto-. *prefix.* Anus; rectum.

proctology. *n.* The field of medicine concerning the anus, the rectum, and the sigmoid colon.

prognosis. *n.* A forecast of the probable outcome of an illness.

proliferation. *n.* Multiplication of cells.

pronation. *n.* Rotating into a prone position, ventral side down; turning of the hand with dorsal surface uppermost.

properties. *n. pl.* The inherent qualities of a substance or structure.

prostate. *n.* A gland located at the base of the bladder almost surrounding the urethra in the male.

protection (radiation). *n.* Protection of patient and operator from excessive harmful exposure to x-rays or radium.

proton. *n.* A positively charged particle in the nucleus of an atom. The nucleus of a hydrogen atom is composed of a single proton.

proximal. *adj.* Near to the central portion or trunk of the body; as the proximal fragment of a fracture, i.e., the fragment nearest the body.

pseudo-. *prefix.* False, spurious.

psoas muscles. Heavy muscles of the spine.

psychiatry. The field of medicine concerning the mind and the personality.

psycho-. *prefix.* Mental.

psychosomatic. *adj.* Pertaining to both mind and body; pertaining to physical conditions resulting from mental causes.

ptosis. *n.* A sagging down in an unnatural position.

pubis. *n.* The bones forming the anterior portion of the pelvis.

pulmonary. *adj.* Pertaining to the lungs.

pulsating. *adj.* Recurring in beats but not having a regular cycle; for example, pulsating current in an x-ray tube.

purulent. *adj.* Consisting of or containing pus.

pus. *n.* The fluid resulting from bacterial infection and body tissue elements attempting to combat the infection.

putrefaction. *n.* Disintegration of protein material from effect of putrefactive bacteria.

pyelitis. *n.* Inflammation of the kidney pelvis.

pyelography. *n.* Roentgenographic examination of the kidney after injection of opaque material.

pylorospasm. *n.* Spasm of the pyloric sphincter.

pylorus, pars pylorica of the stomach. *n.* The lower end of the stomach just before it joins with the duodenum.

pyo-. *prefix.* pus.

pyogenic. *adj.* Caused by pus-forming organisms.

pyonephrosis. *n.* Pus in the kidney pelvis.

pyorrhea. *n.* Infection of the alveolar process about the margin of a tooth.

qd. Every day.

q.v.d. Four times a day.

r. Roentgen.

radiation. *n.* The projection through space of any form of electromagnetic waves.

radiation reaction. The reaction of living tissues to the effects of radiation.

radiation resistance. The resistance of living cells to the effects of irradiation.

radiation therapy. Use of radiation of any type in the treatment of disease.

radiator tube. An x-ray tube having a radiator for the dissipation of heat.

radioactive deposit. The deposit from the natural disintegration of radium known as radium A, B, and C, which is radioactive and is responsible for the therapeutic action of radium.

radioactivity. *n.* The property of spontaneous emission of radiation.

radiograph. *n.* A photographic film which has been exposed to x-rays after they have passed through a part to be examined.

radiography. *n.* The science which deals with the taking of x-ray films.

radiologist. *n.* A physician who uses all forms of radiant energy (x-rays, radium rays, etc.) in the diagnosis and treatment of disease.

radiology. *n.* The science which deals with the use of all forms of radiant energy in the diagnosis and treatment of disease.

radiolucent. *adj.* Partially penetrable by x-radiation.

radium. *n.* A radioactive element used in the treatment of disease.

radius. *n.* The larger of the two bones in the forearm.

rales. Rattle-like sounds, detected by the stethoscope.

ramus. *n.* A branch or process of a bone or vessel.

rarefied area. An area of lessened density.

Raynaud's disease. A disease of the terminal blood vessels of the extremities.

rectify. *v.t.* To change from an alternating to a unidirectional current either by mechanical rectifying apparatus or by valve tubes.

rectifying disc. A device for mechanical rectification of high-voltage currents from alternating to unidirectional.

rectovaginal. *adj.* Pertaining to rectum and vagina.

rectovaginal fistula. An artificial opening between the rectum and the vagina.

rectovesical. *adj.* Pertaining to the rectum and bladder.

rectovesical fistula. An artificial opening between the rectum and bladder.

rectum. *n.* The terminal pouchlike expansion of the large bowel.

red prussiate of potash. A red crystalline chemical used in the reduction of dense overexposed films. Also *potassium ferricyanide.*

regurgitation. *n.* The return flow of fluid in the direction opposite to normal flow, as regurgitation of food.

Reid's base line. A line from the lower margin of the orbit to the external auditory meatus (opening of the ear).

remote-control switch. A control switch which may be operated at a distance from the machine controlled.

renal. *adj.* Pertaining to the kidney.

resistance. *n.* An impediment to the flow of an electric current.

reticular. *adj.* Having the appearance of network.

retro-. *prefix.* Backward, behind.

retrograde. *adj.* Back, or against the natural flow.

retrograde pyelogram. A pyelogram made after the injection of opaque solution from below.

retrograde urography. Examination of the urinary tract after injection of opaque solution from below through catheters inserted into the ureters.

retroperitoneal. *adj.* Behind the peritoneal cavity.

reversal. *n.* (Of a photographic image) the changing of the image so that the part most exposed shows least blackening, and that having least exposure shows greatest.

reversible. *adj.* Capable of being changed about in the opposite direction, as a reversible reaction.

RH. Rhesus factor.

-rhagia. *suffix.* Bursting, break.

-rhapy. *suffix.* Suture.

-rhea. *suffix.* Flow.

rheostat. *n.* A series of resistance coils arranged so that varying amounts of resistance can be introduced into a circuit.

rheumatism. *n.* A disease of the joints.

rheumatoid. *adj.* Resembling rheumatism, as rheumatoid arthritis.

rhinology. *n.* The field of medicine concerning the nose, especially the nasal passages.

ribs. *n.* Curved bones, twelve in number on each side, forming the thoracic or chest cavity.

rickets. *n.* A nutritional disease of the bone affecting children under three years of age.

RLQ. Right lower quadrant.

roentgen. *n.* The primary unit of dosage of x-rays, defined as that quantity of x-ray energy which when the secondary electrons are fully utilized, and secondary radiation from the wall of the chamber is avoided, produces in one cubic centimeter of air at normal temperature and pressure such a degree of conductivity that the quantity of electricity measured at saturation current is one electrostatic unit.

roentgenography. *n.* The use of x-rays in taking x-ray films of a part.

roentgenologist. *n.* A physician who limits his work to the use of x-rays in the diagnosis and treatment of a disease.

roentgenology. *n.* The science which deals with the use of x-rays in the examination and treatment of disease.

roentgen rays. X-rays.

roentgen therapy. The use of x-rays in the treatment of disease.

root-mean-square kilovoltage. The average effective kilovoltage of an alternating-current wave.

rotating target. A target which revolves during operation.

-rrhagia. *suffix.* A bursting forth; especially an abnormal or excessive discharge.

-rrhea. *suffix.* Discharge or flow.

r-unit. The roentgen.

RUQ. Right upper quadrant.

s̄. Without (*sine*).

sacralization. *n.* Enlargement of a transverse process of the fifth lumbar vertebra with encroachment on the sacrum.

sacral vertebrae. The vertebrae below the lumbar spine which fuse to form the sacrum, usually five in number.

sacroiliac joint. The joint between the sacrum and the iliac bone on either side.

sacroiliac strain. Strain of the ligaments of the sacroiliac joint.

sacrum. *n.* The wedge-shaped bone at the lower end of the spine which forms the keystone for the arch of the pelvis bones.

safelight. *n.* A light for a dark room by which films can be safely exposed without fog as a result.

sagittal plane. A plane which divides the body in the midline into the right and left sides.

sagittal suture. Suture or union of the bones of the skull.

saliva. *n.* The secretion found in the mouth which aids in the mastication and digestion of food.

salivary gland. One of the glands located near the mouth which secrete saliva.

sarcoid. *n.* A peculiar disease of unknown origin which affects the bones, lung, skin, and other tissues of the body.

sarcoma. *n.* A tumor, often highly malignant, arising from connective or nonepithelial tissue.

saturation current. The maximum current in an x-ray tube which fully utilizes all electrons available at the cathode for the production of x-rays.

scaphoid. *n.* One of the tarsal bones; the navicular.

scapula, -ae. *n.* The shoulder blade, forming joints with the humerus and clavicle.

scar tissue. Organized fibrous tissue resulting from injury or inflammation.

scattered radiation. The type of secondary radiation which results when x-rays strike an organic substance having a lower atomic weight than aluminum.

Schmorl's disease. Herniation of the nucleus pulposus of the spine.

Schüller-Christian disease. A disease of fat metabolism causing areas of destruction in the flat bones of the skull.

scintillation. *n.* Minute flashes of light observed on a fluorescent screen as a result of spontaneous emission of alpha particles across its surface.

sclerosis. *n.* Hardening of the tissues, usually of the interstitial tissue or bone.

scolio-. *prefix.* Crooked; curved.

scoliosis. *n.* Lateral curvature of the spine.

-scopy. *suffix.* Looking.

scurvy. *n.* A nutritional disease of bone occurring usually in young infants due to vitamin deficiency in diet.

sebaceous glands. Glands secreting oily material for the skin.

secondary circuit, secondary winding. In a transformer, the winding about the iron core, in which a secondary current is induced.

secondary radiation. The radiation set up by radiation when it strikes a solid object.

secrete. *v.* To separate (a liquid) from the blood by action of some glandular structure.

secretion. *n.* A substance separated from the blood by glandular action.

sella turcica (Turkish saddle). The saddlelike bone structure at the base of the skull which shelters the pituitary gland.

semicircular canal. Any of three small canals of the inner ear, shaped like half-circles, which have to do with maintenance of the equilibrium.

semilunar cartilage. The semicircular cartilage in the knee joint.

senile. Affected by weaknesses typical of old age.

-septic. *suffix.* Of putrefaction.

septum, -a. *n.* A membranous partition (of the lung); *nasal septum,* the partition of the nose.

serous fluid. Clear watery fluid secreted by serous membranes of the body, such as the pleural cavity and abdomen.

sesamoid bone. A bone formed in a tendon.

shaft of bone. The long slender tubular portion of bone.

Shenton's line. The curved line representing the relationship between the under surface of the neck of the femur and upper margin of the obturator foramen.

short bones. *n.* Metacarpal, metatarsal, and phalangeal bones of the hands and feet.

siderosis. *n.* A disease of the lungs occurring with prolonged inhalation of fine particles of iron.

sigmoid. *n.* The S-shaped portion of the descending colon as it crosses the pelvic brim.

silicosis. *n.* A disease of the lungs due to prolonged inhalation of fine dust particles of silica.

simple fracture. A fracture having no complicating features; a fracture not connected with the outside air.

sine curve. The wave form of an alternating current.

sinus. *n.* A natural cavity in the bone, containing air, as the paranasal sinuses; a tract in the soft parts offering a pathway for discharge of deep-seated infectious material.

sinusitis. *n.* Inflammation of the nasal sinuses.

six-hour barium meal. A meal containing barium sulfate used to test the motility of the gastrointestinal tract.

skeletal system. Bony structure of the body.

skiograph. *n.* A roentgenogram (an old term).

slipped femoral epiphysis. A disease affecting the epiphysis of the head of the femur, permitting it to slip.

soft. *adj.* (x-radiation) of long wave length, having feeble penetration.

solarization. *n.* The production of a value-reversed photographic image by prolonged exposure of a film to strong light or radiation. *See* reversal.

spark coil. An induction coil.

spark gap. A variable gap between points or spheres, attached across a high-voltage circuit to measure the approximate voltage.

spasm. *n.* Involuntary continuous contraction of a muscle.

spectrograph. *n.* An instrument used in making a photographic impression of the spectrum.

spectrum. *n.* The result of dispersion of waves of radiation of different wave length, for both light and x-rays.

spectrum analysis. Analysis of a substance by observing the interference phenomena which it exhibits on the spectrum.

speed of an x-ray film. Its degree of sensitiveness to x-rays.

sphenoid bone. *n.* An irregular wedge-shaped bone at the base of the skull.

sphenoid, sphenoidal sinus. One of the accessory nasal sinuses.

sphere gap. A variable gap between spheres connected across a high-tension circuit, the purpose of which is to measure the voltage.

sphincter. *n.* A circular muscle which by its contraction closes a canal or pouch.

spicule. *n.* A small fragment, as a spicule of bone.

spina bifida. A congenital deformity of the spine in which the bony arch for the spinal canal is not completely formed.

spinal cord. The portion of the nervous system extending from the brain down through the spinal canal.

spinal fluid. Fluid in the spinal canal surrounding the cord.

spine. *n.* The vertebrae composing the backbone; (of a bone) a short outward projection.

spine of the scapula. The heavy bony process which projects upward and outward from the dorsum of the scapula.

spine of the tibia. The pointed bony projection on the upper surface of the tibia for attachment of crucial ligaments of the knee joint.

spiral fracture. A fracture in which the line of the break runs obliquely up one side of the bone.

spleen. *n.* One of the abdominal organs. It has to do with the disintegration of old blood corpuscles.

splenic flexure. The place where the transverse colon turns in the region of the spleen to descend.

splenomyelogenous leukemia. A fatal disease of the blood characterized by enlargement of the spleen.

spondylitis. *n.* Inflammation of the spine; arthritis of the spine.

spondylitis deformans. *n.* Deforming arthritis of the spine.

spondylolisthesis. *n.* Luxation of the vertebrae, usually of the fifth lumbar forward on the sacrum.

spontaneous. *adj.* Without apparent cause.

sprain. *n.* Tearing of ligaments.

Sprengel's deformity. A congenital deformity of the scapula.

squamous portion of the temporal bone. The flat expanded portion of this bone which forms the temple of the head.

stabilizer. *n.* An instrument used in an x-ray machine to render the milliamperage output of the x-ray tube constant.

standard position. An accepted position for radiographic examination.

staphylococcus. *n.* Spherical microorganisms (cocci) arranged in bunches, like grapes.

-stasis. *suffix.* Stoppage; position.

static electricity. Electricity of the type produced by friction, for example, between hard rubber and silk.

stellate. *adj.* Star-shaped.

stem radiation. The radiation emanating from the stem of the target of an x-ray tube.

stenosis. *n.* A constriction of the lumen or opening of a canal.

Stenver's position. A position for radiographic examination of the petrous portion of the temporal bone.

step-up, step-down transformers. Devices for increasing or decreasing voltage.

stereogram. *n.* A radiograph taken stereoscopically for stereoscopic examination.

stereoscope. *n.* An instrument consisting of two illuminating boxes for the illumination of two separate radiographs taken from two positions of the target at a distance equivalent to the interpupillary distance, two and one-half inches.

stereoscopic examination. An x-ray examination which produces an impression of the third dimension.

sternoclavicular joint. The joint between the sternum and clavicle.

sternum. *n.* The breastbone, composed of three segments: the manubrium, the body (gladiolus), and the xiphoid (ensiform) process.

stethoscope. *n.* An instrument used by physicians for listening to sounds produced within the body.

stomach. *n.* The upper expanded portion of the gastrointestinal tract for the digestion of food, connecting with the esophagus above and the duodenum (first portion of small bowel) below.

stomat-. *prefix.* Mouth.

-stomy. *suffix.* Mouth, opening.

strangulation. *n.* The forcible protrusion of a structure through a small opening so that the blood supply is cut off.

streptococcus. *n.* Spherical microorganisms arranged in chains.

stricture. *n.* A narrowing of the lumen of a normal canal or cavity by scar-tissue contraction.

STS. Serology test for syphilis.

styloid process of the radius. The process of the lower end of the radius near the wrist joint.

styloid process of the ulna. The prominent process of the lower end of the ulna near the wrist joint.

sub-. *prefix.* Below.

subarachnoid spaces. Spaces beneath the arachnoid covering of the brain.

subchondral necrosis. A disease of the spine occurring during the developmental period.

subcoracoid dislocation. A dislocation of the head of the humerus below the coracoid process of the scapula.

subcutaneous. *adj.* Under the skin.

subdiaphragmatic. *adj.* Under the diaphragm.

subglenoid dislocation. A dislocation of the head of the humerus below the glenoid cavity.

subphrenic. *adj.* Under the diaphragm.

subphrenic space. The space beneath the diaphragm.

substernal. *adj.* Situated below the breastbone.

Sudeck's atrophy. Acute bone atrophy after an injury.

sulfonamides. A group of chemotherapeutic drugs derived from sulfanilamide; sulfa drugs; sulfas. Examples: sulfadiazine, sulfamerazine, sulfamethazine.

super-. *prefix.* Over.

superior. *adj.* Above.

supernumerary bones. Bones in greater number than normal; extra bones.

supination. *n.* Turning of the hand with the palm uppermost.

suppression. *n.* Elimination, as the suppression of a phase of current with a self-rectified x-ray tube.

suppurate. *v.* To form pus.

supra-. *prefix.* Above.

supracondylar. *adj.* Above the condyle.

suprarenal glands. Ductless glands located above the kidneys which have to do with regulation of blood pressure.

surge. *n.* A sudden high-voltage discharge noted in a high-tension line during the operation of high-voltage apparatus, probably due in part to condenser effects of overhead wiring.

surge arrester. A piece of high-resistance material introduced across high-voltage lines to arrest electrical surges.

suture. *n.* The line of union between bones of the skull.

symphysis. *n.* The union of two paired bones.

symphysis pubis. The bony arch of the front of the pelvis where the two pubic bones join.

syn-, sym-. *prefix.* Together, with.

synchronous motor. *n.* A motor so wound that it will turn with the same number of revolutions as the generator which produces the current which runs it.

synchronous timer. A timer which is operated by a synchronous motor; it breaks the primary current at the point of zero potential in the electrical cycle.

syndrome. *n.* A group of symptoms and signs occurring together in such a way as to indicate the existence of a common cause. A specific syndrome is characteristic of a disease entity.

synovial fluid. The thin watery fluid found in a joint, secreted by the synovial membrane lining the joint.

synovial membrane. The membrane lining a joint which secretes synovial fluid.

syphilis. *n.* A constitutional disease usually acquired by venereal infection which can affect any of the structures or tissues of the body.

systole. *n.* The stage of contraction in the heart beat cycle.

talus. *n.* The tarsal bone which with the tibia forms the ankle joint. Also *astragalus.*

target. *n.* The anticathode or positive terminal of an x-ray tube which receives the impact of electrons in the production of x-rays.

tarsal bones. Irregular bones of the foot between the ankle and metatarsal bones.

tele-. *prefix.* At a distance.

teleroentgenograph. *n.* Roentgenograph taken from a distance of six feet.

temperature, optimum. For development, 68° F.

temperomandibular joint. The joint between the temporal bone and the lower jaw, located just anterior to the ear.

temporal. *adj.* Pertaining to the temple region.

temporal bone. An irregular bone at the side and base of the skull.

tendo achillis. The heavy tendon of the extensor muscles of the leg which attaches to the heel.

tendon sheaths. Synovial sheaths in which the tendons run.

testes. *n. pl.* The male sex glands.

tetra-. *prefix.* Four.

tetraiodophenolphthalein. *n.* A drug used to render the bile opaque to x-rays so that the gallbladder can be visualized. Also *iodeikon.*

T-fracture. A fracture shaped like a letter T extending not only above the condyles of the end of a long bone, but between the condyles as well.

therapeutics. *n.* The study of medical treatment.

therapy. *n.* Medical treatment.

thermoelectron. *n.* An electron emitted by a heated body, as by the filament of an x-ray tube.

thigh. *n.* The portion of the lower extremity between hip and knee.

thoracic. *adj.* Pertaining to the chest.

thoracic cavity. The chest cavity.

thoracic spine. The portion of the spine to which the ribs are attached. Also *dorsal spine.*

thoracic vertebrae. The vertebrae to which the ribs are attached, twelve in number. Also *dorsal vertebrae.*

thoracoplasty. *n.* An operation on the chest which permits collapse of the chest wall from removal of a portion of a number of the ribs.

thorax. *n.* Chest.

thorium dioxide. A drug used for intravenous injection to aid in radiographic examination of liver, spleen, and circulatory system.

thorotrast. *n.* A drug used to visualize the liver.

thrombus. *n.* The clotting of blood within a vessel.

thymus. *n.* A ductless gland located in the chest beneath the upper portion of the sternum, in children up to two years of age.

thyroid gland. A ductless gland located in the neck, having to do with the metabolism of the body.

tibia. *n.* The larger of the two bones of the leg.

t.i.d. Three times a day.

timer. *n.* An instrument used on an x-ray machine to complete the electrical circuit so that x-rays will be produced for a limited period of time. *See also* integral timer *and* synchronous timer.

tinnitus. Ringing in the ear.

tolerance dose of x-rays. The dose of x-rays which will be absorbed by the skin without injury.

tomograph. *n.* A laminograph.

-tomy. *suffix.* Operation of cutting (**-ectomy:** removal by cutting).

tone, tonus. *n.* Partial contraction of a muscular structure due to continuous minute nervous stimulation; incomplete relaxation.

topography. *n.* The mapping out or description of the location of a structure or organ.

torsion. *n.* Twisting.

torus fracture. A folding or pressure fracture.

toxic. *adj.* Poisonous.

trachea. *n.* The windpipe by which air is introduced into the lungs.

traction. *n.* Pull applied to the ends of a fracture for the purpose of adjusting the fragments and overcoming shortening.

trans-. *prefix.* Through; across.

transformer (x-ray). *n.* A piece of electrical apparatus consisting of a ring of iron with two separate coils of wire, the primary coil consisting of a few turns of heavy wire, the secondary coil consisting of many turns of fine wire, the entire apparatus being immersed in oil for insulation. Its purpose is to transform the voltage.

transmutation. *n.* The changing of one element into another; as the transmutation of radium into radon.

transverse. *adj.* Extending out laterally or sidewise, as transverse processes of vertebrae.

transverse colon. The portion of the colon which goes transversely across the upper abdomen.

transverse plane. A plane which divides the body horizontally at any level.

transverse processes of vertebrae. The bony projections which extend outward on either side of a vertebra to give attachments to muscles.

trauma. *n.* 1. Wound or injury. 2. In psychiatry, a horrifying or shocking experience.

traumatic. *adj.* Due to injury.
tri-. *prefix.* Three.
trichobezoar. *n.* A hair ball in the stomach.
trochanter. *n.* A heavy rounded projection of bone for the attachment of muscles, as the greater and lesser trochanter of the femur.
trochlea. *n.* The inner portion of the articular surface of the lower end of the humerus for articulation with the ulna.
tropho-. *prefix.* Nourishment or nutrition.
tubercle, tuberosity. *n.* Smaller rounded projections of bones, as the tuberosities of the humerus.
tuberculosis. *n.* A disease produced by the tubercle bacillus.
tuberosity of the tibia. The rounded prominence on the front aspect of the tibia upon which one rests when kneeling.
tularemia. *n.* An undulant fever transmitted by infected rabbits and other animals.
tumor. *n.* An abnormal swelling; an abnormal multiplication of cells forming a new growth, as cancer.
turbinate bones. Bones projecting in the nasal cavities.
Turkish saddle. Sella turcica.
twenty-four hour meal. A meal given in gastrointestinal examination to test the motility of the tract twenty-four hours after ingestion.

ulcer. *n.* An open sore on a cutaneous or mucous surface.
ulna. *n.* The smaller of the two bones of the forearm.
ultra-. *prefix.* Beyond.
ultramicroscopic. *adj.* So small as not to be visible even with a microscope.
ultraviolet. *n.* An invisible portion of the spectrum of radiation having wave lengths just shorter than the range of visible violet light.
umbilicus. *n.* The navel.
unerupted tooth. A tooth which remains in the alveolar process.
unilateral. *adj.* Pertaining to one side of the body.
union of epiphysis. The joining of the epiphysis with the shaft when it ceases to function as a bone-forming structure.
union of a fracture. Growing together of two ends of a fracture with new bone formation.
unipolar. *adj.* Having one pole.
uranium. *n.* A radioactive element.
ureter. *n.* The tube which conveys the urine from the kidney to the bladder.
ureteral catheterization. Introduction of small ureteral catheters through a cystoscope into the ureters.
ureterography. *n.* Roentgenographic examination of ureters after injection with opaque material.
urethra. *n.* The tube which conveys the urine from the bladder to the outer orifice.
urethrography. *n.* Radiographic examination of the urethra after filling it with opaque material.
-uria. *suffix.* Condition of the urine or presence in the urine.

urography. *n.* Roentgenographic examination of the urinary tract.

urology. *n.* The field of medicine concerning the kidneys, the ureters, the bladder, and the urethra, as well as their accessory glands.

urticaria. *n.* Hives.

uterine. *adj.* Pertaining to the uterus.

uterus. *n.* The womb.

vacuum. *n.* A volume devoid of gas.

vacuum tube. Any tube in which the space has been reduced to a vacuum.

vaginitis. *n.* Inflammation of the vagina.

valence. *n.* The number of ions with which a substance is capable of combining; the absolute valence of an atom is the number of electrons or bonds with which it attaches itself to other atoms in a molecule.

valve tube. A vacuum tube with two electrodes, one of which is usually an incandescent filament, the other an unheated plate, the purpose of which is to permit the passage of one phase of an alternating current.

valvular. *adj.* Pertaining to the valves of the heart.

varices. *n. pl.* Enlarged and tortuous veins.

varicose veins. Abnormal dilated tortuous veins, usually seen in the legs.

vaso-. *prefix.* Vessel.

vasography. *n.* A method of demonstration of vessels, arteries, veins or lymphatics by roentgen examination after injection of opaque material.

VD. Venereal disease.

veins. *n. pl.* The blood vessels which carry the blood back from the extremities to the heart.

venography. *n.* A method of demonstrating venous structure by roentgen examination after intravenous injection of opaque media.

ventral. *adj.* Front.

ventricles. *n. pl.* Reservoirs or spaces.

ventricles of the brain. Cavities in the brain containing cerebrospinal fluid.

ventricles of the heart. The right and left chambers of the heart.

ventriculography. *n.* Roentgenographic examination of the skull after removing the cerebrospinal fluid and filling the ventricles with some medium of greater or lesser density, for diagnosis of brain tumor.

vertigo. *n.* Dizziness.

vesicle. *n.* A bladder; the sac or pouch for the collection of bile or urine; a small blister of the skin.

Victoreen. *n.* An instrument for measurement of x-ray output in "r" units.

visceral. *adj.* In close relationship to a viscus or organ.

viscus. *n.* A body organ, such as the liver, spleen, or kidney.

volar. *adj.* Referring to the palm or sole, the ventral side of wrist or forearm.

volt. *n.* The fundamental unit of measurement of difference in potential of electrical charges, indicating the quality or pressure of electricity. It is defined as the pressure of electricity necessary to force one ampere of current through one ohm resistance.

voltmeter. *n.* A meter for the measurement of voltage or difference in potential or pressure between two points in an electric circuit, usually connected across the circuit.

volvulus. *n.* Obstruction from the twisting of a loop of the bowel.

vomit. *v.t.* To evacuate the stomach by violent spontaneous contractions.

Wassermann test. A test for syphilis.

Waters' position. The verticomental position for examination of the nasal sinuses.

watt. *n.* Energy per second of electricity.

wave length. The distance between the peaks of the waves in any wave form, such as light, x-rays, and other electromagnet forms.

xiphoid process. The ensiform process.

x-rays. *n. pl.* Electromagnetic radiations emanating from the point of impact, where electrons traveling at high speed are stopped suddenly.

x-ray spectrograph. An instrument for the photographic recording of an x-ray spectrum.

x-ray spectrum. The spectrum of x-rays produced by causing a beam of x-rays coming from an x-ray tube to strike a diffraction grating produced by the cleavage plane of certain crystals.

x-ray tube. A vacuum tube used for the production of x-rays.

zygoma. *n.* The bony arch which provides the prominence of the cheek bone.

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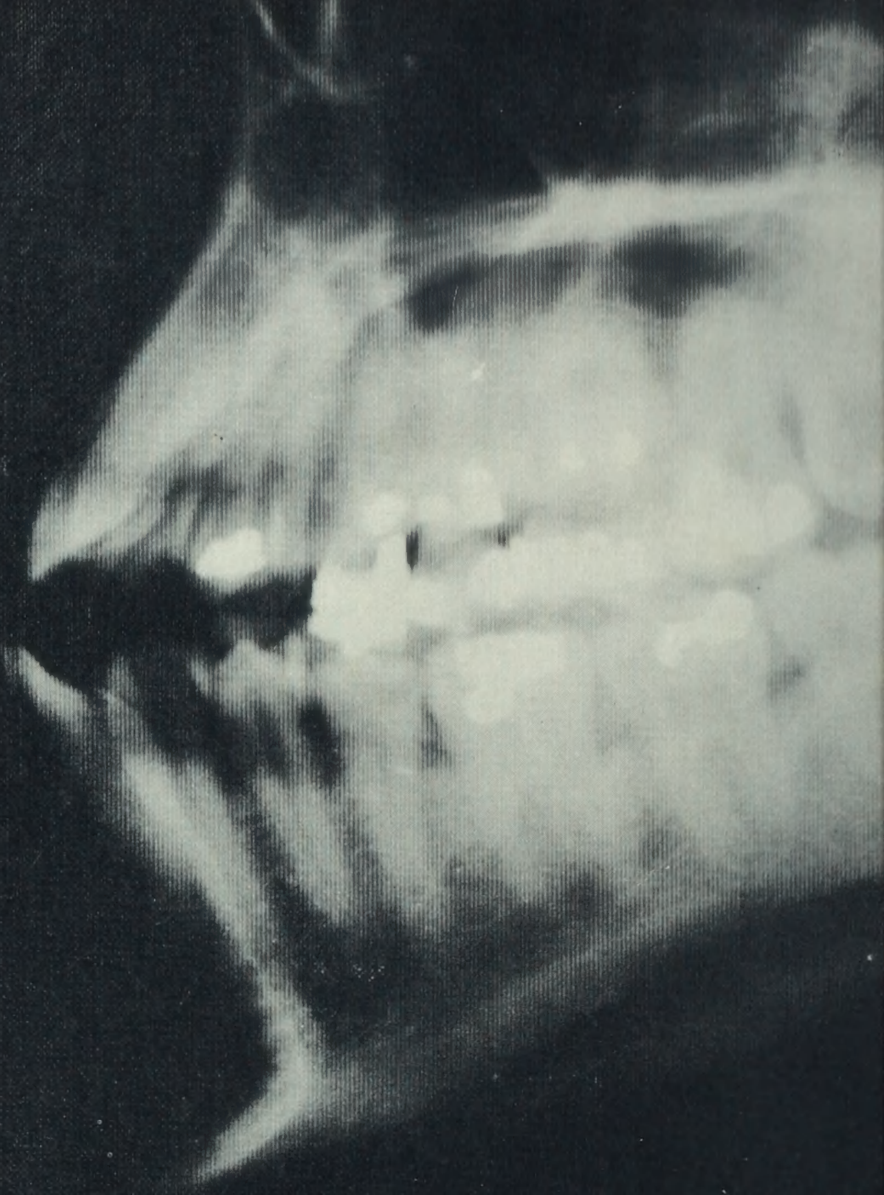

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